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A TREATISE

ON THE METHOD OF

GOVERNMENT SURVEYING

AS PRESCRIBED BY THE UNITED STATES CONGRESS, AND COMMISSIONER OF THE GENERAL LAND OFFICE.

WITH COMPLETE

Mathematical, Astronomical and Practical Instructions,

FOR THE USE OF

UNITED STATES SURVEYORS IN THE FIELD, AND STUDENTS WHO CONTEMPLATE ENGAGING IN THE BUSINESS OF PUBLIC LAND SURVEYING.

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BY

SHOBAL V. CLEVENGER,

U. S. DEPUTY SURVEYOR.

THIRD EDITION REVISED.

NEW YORK
D. VAN NOSTRAND, PUBLISHER,
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MEYERS PRINTING CO. Minneapolis

TO THE

HON. COLUMBUS DELANO,

SECRETARY OF THE INTERIOR,

WASHINGTON, D. C.,

THIS

TREATISE IS RESPECTFULLY DEDICATED

IN

Memory of Pleasant Conversations.

REPRINT PREFACE

This book is one in a series of public land surveying references from the late nineteenth century. It belongs in a "family" of books from this period, others being Burt, Dorr, Hawes, Hodgman, and the several government manuals and restoration circulars. Each of these books was written for essentially the same reason—to fill a need for additional instructions and principles for understanding the surveying and retracement of public land lines. Each author sensed some particular specific omission or lack of explanation in available instructions and sought to fill the gap. In this sense, the several books provide a set of excellent references on the public land survey system, each prepared from a slightly different perspective. This treatise, first published in 1874, went through several editions.

Clevenger was born March 24, 1843, and died on his birthday in 1920. His early schooling was in New Orleans. Later he lived in St. Louis and areas of Kansas. He served in the U.S. Engineer Corps during the Civil War where he gained experience in building bridges and railways. Later, in Montana, he served as justice of the peace, probate judge, court commissioner, and revenue collector. His primary surveying experience was in the Dakotas. He also did some railway and telegraph line building. Clevenger had varied interests. After losing his government position as surveyor through politics, he developed his interest in medicine and obtained his M.D. degree in 1879. He made several significant contributions in the fields of psychiatry and neurology and gained an international reputation in those fields. Clevenger, as many such versatile individuals often do, possessed a desire to invent, was ahead of his time in many ways, had an extreme dislike for sham and corruption, and sought to improve and reform whenever he could.

This treatise on surveying is somewhat more academic in style than others from the period. Nevertheless, it contains practical explanation of field principles and represents a significant historical contribution to the literature on nineteenth century public land surveying methods by a U.S. Deputy Surveyor.

R. Ben Buckner and *Carlisle Madson,* Surveyors

SEPTEMBER, 1978

PREFACE.

THERE never having been published a work professing to give information upon the subject of Land Surveying, which did not, so far as Government Surveys are concerned, fall so much short of its object as to invariably disappoint the student, and even the United States surveyor, who would have found a treatise upon the subject of frequent use; the author has been encouraged to publish this book, in the belief that it will be found serviceable alike to the novice and practiced deputy. An attempt has been made to fully explain and classify the system, and, probably, nothing has been omitted which would be of any value, while everything which cannot be of use in the field or an aid to the learner has been excluded.

The nearest approach to a Manual was Burt's treatise on his "Solar Compass," but, as its name would indicate, it dealt principally with that instrument, and only incidentally gave information upon the land system of the United States.

There are numerous excellent school-books on Surveying, calculated to impart all that is of theoretical value in a mathematical course, and evident pains have been taken to make them exhaustive; but invariably Government Surveys are touched upon too lightly. In the cases of Gillespie, Robinson, Loomis, and similar writers, this can be accounted for by their never having given the matter more than a cursory examination; with Burt, however, it is different. As before remarked, he wrote more about the solar compass and its application, than about surveying, and, at the date of the publication of his book, the present system had not reached its now almost perfect condition —an altogether different method for bases and principal meridians being in vogue.

Burt gives many useful tables and hints in his work, which has won for it as much consideration as his truly great invention

— the solar compass; but, in the progress of all things, a more comprehensive treatise is in demand and is herewith presented to United States surveyors, in the hope that it will be found serviceable, inasmuch as it has been compiled principally from the author's experience in the various classes of field-work to which it alludes.

One of the oldest deputy surveyors in the Union, Colonel I. N. Higbee, has kindly examined each page of the MS., and appends his testimonial. This gentleman is still connected with United States surveys, his first contract from the Government being dated January 1st, 1838.

The United States Manual and its Supplement have been carefully deferred to, as far as possible, but the frequent ambiguities in those "Instructions" compel such an elucidation of their contents as will render much reference to them unnecessary.

UNITED STATES SURVEYOR-GENERAL'S OFFICE,
DAKOTA TERRITORY,
YANKTON, *December* 1, 1873.

S. V. CLEVENGER,
U. S. Deputy Surveyor.

SIR: Having carefully read the MS. of your Treatise on the Method of Government Surveying, I take pleasure in saying that it is something that has long been needed, and advise all surveyors to make themselves perfectly conversant with your book before entering upon any kind of surveys.

I have been connected with United States surveys for over thirty years, the last eleven years as chief clerk in a Surveyor-General's office, and during that time I have known several contracting individuals to fail in the execution of the surveys contracted for, because they did not possess the requisite knowledge contained in your book.

Hoping the new work will meet with merited appreciation and success, I am, sir,

Yours truly,

I. N. HIGBEE,
Chief Clerk U. S. Surveyor-General's Office.

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INTRODUCTION.

THE present system of dividing the public lands is the outgrowth of many years' experimenting, theorizing, and failure. The earlier acts of Congress on the subject being those dated May 18th, 1796—which provides that sections of a mile square shall contain 640 acres, as nearly as may be,—May, 10th, 1800, and February 11th, 1805.

The mathematical impossibility of governing the lines by the true meridian and dividing large portions of the globe into rectangular parallelograms was evidently recognized by the framers of those first acts concerning surveys, but their instructions in regard to the method of extending the work to future operations convicts them of being unaware of the magnitude and importance the Land Department was to assume in after years.

It is needless to recount their suggestions and the many embarrassing errors a strict adherence to orders caused, but we can take satisfaction in believing that very little, if any, improvement can be made upon the system attempted to be explained in this book, when faithfully and skillfully carried out.

Ever since the governmental foundations were laid, the Surveying Department has been harassed, and to a certain extent brought into disrepute, by the action of ignorant, over-confident, or untrustworthy contractors, in making unskillful or fraudulent surveys. These matters, however, are receiving their due share of attention by the proper officials, and eventually it will become a matter of extreme difficulty to commit any such outrages upon the public.

Ignorance of the elements of surveying on the part of the contractor, is exhibited where he has not run his lines sufficiently parallel with the exterior boundaries, causing the inclosed areas to fall short or overrun absurdly ; in attempting to close the northernmost set of lines to the standard parallel corners, which belong only to the work north of the parallel ; in

false meanders, creating erroneous area plats; in mistaking distances across impassable obstacles, etc.

The office of General Land Commissioner, in the Department of the Interior, is at Washington, D. C., and to him all Surveyors General report.

The assistants of the Surveyors-General, who usually have their offices in the capital or principal city of their district, consist of chief clerks, draughtsmen, assistant-draughtsmen, transcribing clerks, accountants, and deputy surveyors. Each general has his selected corps of deputies, to whom he intrusts his allotted field-work, the pay for which is appropriated by Congress, in advance of each fiscal year's operations, and the rate of compensation per linear mile is also fixed by Congress under the advice of the Commissioner, and varies from $6 to $20, according to the locality, timber and mountain surveys rating highest. An application for a surveying contract must be made to the Surveyor General of the district, and set forth in writing where and when the applicant had previously surveyed for the government, or, if having served as an assistant to a deputy, state in what capacity, and how long, and give such other satisfactory evidence of ability and good character as the circumstances admit.

Having complied with this rule, the aspirant is by no means entitled to a contract, as the Surveyors-General are hampered by no regulations in the selection of their deputies, beyond being accountable for knowingly employing ignorant or dishonest persons.

Should the Surveyor-General award a contract to the applicant, it is necessary to give bonds in double the estimated amount of the value of the work contracted to be done, and the work is apportioned to deputies in the order of their experience and ability, sub-dividing to the younger, townshiping to the older, and standard lines only to the oldest and most competent deputies. By this plan the gross errors of the unskillful surveyor are confined to a smaller area, and, if necessary, remedied at his expense, without detriment to adjoining surveyors.

While the pay for government work is large, it must be remembered that the main object in rendering it remunerative is to compensate the engineer for the time necessarily expended through years of training and study, as well as to incite him to

return faithful work, and although the expense of surveying is very much to the government, when fully and properly performed, it by no means equals the expense to which the contractor is subjected morally, mentally, corporally, and pecuniarily should he from any cause fail to obey "Instructions."

Before starting for the field the deputy is provided with plats of the exterior lines of his work, describing the corners from and to which he runs and closes; the variation of the magnetic needle on each mile of exterior line, with such other details as may enable him to properly identify the country he traverses. These plats the deputy returns to the office when his work is completed, with a sketched topographical display of the interior country, showing the hills, ravines, forests, streams, lakes, etc., thus materially assisting an explanation of his field notes. From the notes and these sketch-plats, accurate plats and transcripts are made and forwarded to the Commissioner by the general, when, after a careful revision, the pay account is audited, and the United States Treasury liquidates by draft sent direct to the deputy.

This routine requires much labor and time, frequently occupying six months; but it can be taken as an evidence of the care exercised throughout by the officers and clerks to whom these matters are intrusted.

While it is possible for the deputy to perform his work without much knowledge of trigonometry, it must occasion him embarassments, and cause him to resort to absurd and even erroneous expedients, the results of which manifest themselves unexpectedly in augmented forms, probably many miles from their origin, creating the alternative of what is called shrinking, fudging, returning false notes, or laboriously correcting and destroying the work of days, and, in some cases, weeks.

Aside from the inconveniences attending the efforts of the uninformed contractor, the intelligent surveyor certainly derives unbounded satisfaction in the consciousness of thoroughly understanding what he is about, and that in every phase of his duties no exigency can arise to which he is not superior, and that under all circumstances he is perfectly aware of the causes and effects of the problems he is constantly encountering and solving.

It is precisely as it is in every business and profession, the best informed has the advantage in every respect.

As it is expected that this book will fall into the hands of

those whose mathematical information is not very profound, but who may be ambitious to excel in all that pertains to the business of land surveying, a course of study is here recommended which, if diligently pursued, will soon enable the student to enter the lists with all competitors.

This course pre-supposes a knowledge of algebra and geometry:

Loomis's "Trigonometry and Logarithms," Robinson's, Gummere's, Murray's, and Gillespie's works on "Surveying;" Robinson's "Astronomy;" Burt's "Solar Compass," Gurley's "Instrument Manual," "Nautical Almanac."

These will suggest a much more extensive selection from D. Van Nostrand's list, or the catalogues of other scientific book publishers.

During the preparation of this treatise, frequent reference has been made to the following authors on mathematics, astronomy, physics, and other subjects:

Burt, Gillespie, Ganot, Robinson, Chambers, Watson, Chauvenet, Henck, Webb, Attfield, Brande, and Proctor.

The government system of surveys, the author hopes he has fully embodied in such a manner as to impart all the information attainable upon the subject.

PART I.

THE INITIAL POINT.

In commencing the division of public lands in unsurveyed territory the first subject for consideration is the Initial Point, unless the district in which proceedings are about to be inaugurated is conveniently situated near surveyed land. The location of this monument involves questions mainly of convenience, such as its contiguity to the field of immediate operations; its nearness to the most valuable of the lands to be surveyed in future; so far as admissible, its conspicuousness in being situated at or near the forks of great streams, the summit of a noted peak, etc., and, if the country to be surveyed is very large, it is desirable to have the Initial Point placed somewhat centrally. Care is also taken to ascertain its geographical position, and as the lines are extended this enables the determination by estimation of the longitude and latitude of every other part of the country through which the lines may be run.

The Initial Point should be perpetuated by a substantial monument of solid masonry or metal, suitably marked as the Commissioner of the General Land Office may direct.

THE PRINCIPAL BASE.

After the Initial Point has been satisfactorily established, lines are run, east and west, therefrom, and marked at each half mile, or 40 chains, with a quarter section corner, and at each mile, or 80 chains, with a section corner. (See Corner Building, Part III.)

All principal lines should receive much care in their construction, as there are no means for discovering by "closings" any mis-tally or similar error, which, if made, would destroy the usefulness of portions of the survey, and cause erroneous lines to be multiplied if suffered to remain uncorrected.

Two sets of chain-men, at least, should be employed upon principal lines, and the work tested at intervals astronomically,

the extremes of each line determined to be in their proper longitude, and the entire line to be in one parallel of latitude; then the base should be retraced and all imperfections obliterated.

Sextants and solar compasses should be used in this class of surveys, and a good chronometer, or pair of chronometers, should also be carried by the surveyor.

The difficulties experienced in projecting a parallel of latitude are fully discussed in this work under the headings of Convergency and Standard Parallels.

THE PRINCIPAL MERIDIAN.

From the Initial Point the Principal Meridian is extended north and south, marked as other lines at every 40 and 80 chains by quarter section and section corners, the same as the principal base line.

This survey can be carried forward more rapidly than parallel work, because the true meridian, after once having been carefully started upon, is a line that can be "back sighted," and does not require the calculating attention the base should always receive. Nevertheless, there are abundant opportunities for mistakes, and the same precautions should be adopted, the extra chain-men used, and astronomical proofs of the correctness of the line, both as to its length and constancy of course, deduced, before the work should be used to govern subsequent surveys.

The latitudes should be determined by a sextant, and the longitudinal corrections by chronometers, and, where possible, by telegraph.

LIST OF PRINCIPAL MERIDIANS.

Ohio public surveys are controlled by several initial points, and by the 1st Principal Meridian which forms the boundary line between Ohio and Indiana.

Indiana surveys are governed by the 2d Principal Meridian.

Illinois, 2d, 3d, and 4th.

Wisconsin, 4th.

Minnesota, 4th and 5th.

Dakota, 5th and 6th.

Iowa, Missouri, and Arkansas, 5th.

Kansas, Nebraska, and most of Colorado, 6th.

MICHIGAN, the Michigan meridian.

FLORIDA, the Tallahassee.

ALABAMA, the Huntsville and St. Stephen's meridians.

MISSISSIPPI, the St. Stephen's, Choctaw, and Washington.

LOUISIANA, east of Mississippi river, the St. Helena, and west of the river the Louisiana meridians.

NEW MEXICO, the New Mexico meridian.

ARIZONA, the Gila and Salt River meridians.

UTAH, the Great Salt Lake meridian.

NEVADA, the Mount Diablo.

MONTANA, the Montana.

CALIFORNIA, the Mount Diablo, San Bernardino and Humboldt meridians.

OREGON and WASHINGTON, the Willamette meridian.

The principal base is represented in Fig. 1, extending east and west, and the principal meridians north and south from the Initial Point.

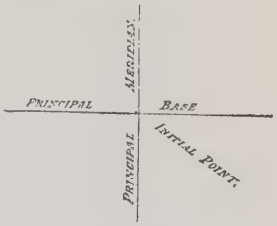


FIG. 1.

THE STANDARD PARALLEL.

Where the Principal Base is proposed to govern a great amount of surveying south of about latitude 35° North, the starting-point from which to run the first Standard Parallel South of the Base line, should be thirty miles south of the Initial Point; but where the Principal Base is situated in a high latitude, all starting-points for Standards either north or south of the Base should be situated at twenty-four miles or some multiple of twenty-four miles from the Initial Point on the Principal Meridian.

The reason of this difference being that near the equator convergency of meridians has much less influence upon a distortion of square work than exists near the poles, consequently a meridian line can be carried through the field a longer distance in lower latitudes before closing, than in high latitudes. The deputy or learner is again referred to "Convergency," where

this matter is treated, and here, once for all, let the student be advised to fully post himself on this subject before undertaking the simplest kind of government work, as it is a matter that will be encountered at every point in actual field operations.

For the purpose of being explicit, throughout, the Standard Parallels will be considered as twenty-four miles apart, the Principal Base being, in nearly every respect, the same as a Standard Parallel.

The figure represents the 1st Standard Parallel South of the Principal Base. Another Standard twenty-four or thirty miles south of this and parallel with it would be denominated the 2d Standard Parallel South. The first Standard north of the Base is therefore called the 1st Standard Parallel North, etc.

FIG. 2.

These standards require the employment of two sets of chain-men with the usual corps of assistants, as in running other lines, and should never be run with any instrument inferior to Burt's Solar Compass.

Under the headings of Chaining and Corner Building will be found special instructions for Standard and Guide work, and it will be noticed that as the corners built on this line are not common to any of the sections south of the standard, there are three instead of four pits dug at each corner, one placed north, and the others east and west of the mound.

The Standard Parallel between the Principal and Guide Meridians, or between two Guides, is forty-two miles in length, generally. At the forty-second mile the Guide Meridian is started north, and runs twenty-four miles, closing at the Principal Base in the case of the 1st Standard South being the starting-point, otherwise closing to another Standard.

In constructing Standards it is necessary to remember that an east and west course *produced*, is not at right angles to a meridian line; consequently, sight stations should either be closer together than 30 chains, in latitudes between 35° and 45° North, or proper allowance made, as explained in the article upon Convergency. A persistent distance of half-a-minute of longitude in arc, between flagman and compass-man, will bear the

Standard too far south, and cause the length of the Guide Meridian to fall outside of reasonable bounds. In addition to creating a Guide Meridian thirty miles in length, in surveying districts in the latitude of the Southern States, it is also customary to extend the Standard parallel to the length of forty-eight miles, for the reasons previously mentioned. Surveyors in such cases can easily adapt the instructions, tables, and formulæ of the 24 by 42 miles Check, almost exclusively dealt with in this work, to Guides of thirty, and Standards of forty-eight miles in length.

THE GUIDE MERIDIAN.

The first Guide Meridian west of the Principal Meridian is run and marked as a meridian of longitude line, with mounds for corners as upon other lines, but with four pits placed to the cardinal N., S., E., and W. points at each corner, except the starting and closing.

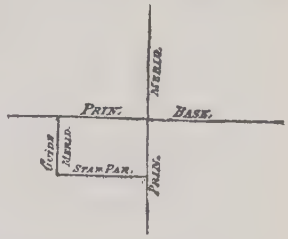


Fig. 3.

The length of the guide should be 24 miles, but, allowing for difference of chaining, instrumental errors in running the Standard, and other inaccuracies, 4.50 chains over or under the 24 miles should be ample closing limit. Frequently, however, as will be explained in Irregularities, closings are made very much shorter or longer, and justified by circumstances, but while the government has found it necessary to impose no closing limit in this case, the field notes must set forth plainly the causes of any apparently bad closing; and in really unjustifiably long or short closings the notes cannot be accepted.

The Check included by the Principal Base and Meridian, and the Standard and Guide, would be a rectangular parallelogram if the earth were a plane instead of a spherical surface.

The figure (4) represents standards and guides projected east and west of the Principal Meridian, closing to the Principal Base.

If the length of the Standard is 42 miles, and the distance from a to b upon the Principal Base is also 42 miles, the Guide Meridian will not close at a, but will intersect the base at a point east of a depend-

Fig. 4.

ing upon the latitude of the work, sometimes over a quarter of a mile distant. In like manner, where b to a' is 42 miles, the first Guide to the east of the Principal Meridian will close west of the point a'.

This is better demonstrated by Fig. 5, wherein $ab=42$ miles of Principal Base, $cd=42$ miles of Standard Parallel, $Pbd=$ Principal Meridian.

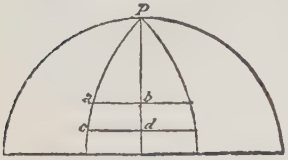


FIG. 5.

It is evident that the Guide Meridian cP passes through the Base ab east of a.

Any excess or deficiency in the length of the Guide Meridian is thrown into the last half-mile which closes to the Standard Parallel or Base, and at the point of intersection the corner is built with the dimensions of Township Corners, and three pits dug, *south*, east, and west, as this closing corner is common to the two townships *south* of the Base.

The distance to the nearest corner belonging to the Base line is then measured from the closing corner mentioned, and noted.

Figure 6 illustrates the last mile of the Guide Meridian closing to the Base. 40 chains north of the last section corner on the Guide is the quarter section corner, and the Base line has been intersected 36 chains from the quarter section corner, at a point 19.55 chains east of the corner to the Guide Meridian, starting north from the Base.

FIG. 6.

Should the length of the last mile overrun 80 chains, no section corner is to be built except upon the Base. For instance, if the distance from the quarter-section corner was 43.00 chains, instead of 36 chains, as above, there must be no corner built at 40 chains north of the quarter-section corner, but the line should be continued up to the Base, regardless of its length.

It need not be supposed that the Guide will always close with regard to its proper convergency, as will be ascertained by experience, nor does the government require that it should be made to do so. Some deputies have cast suspicion upon what might have been otherwise honest work, by endeavoring to "swing" their Guides into a calculated place, when there hap-

pened to be features existing upon adjacent lines rendering the usual closing impossible.

The Surveyor-General's instructions specifying no closing limit in this matter, is evidence that the department recognizes the necessity for leaving the deputy intrusted to exert his best skill to make the proper closing, and faithfully report it, depending upon subsequent surveys of interior lines to prove the correctness of the notes.

From the accompanying ideal plat, an idea can be formed of the appearance in the field of the diverse character of the closings, etc., produced in tiers of Checks, as the trapezoidal figures produced between parallels and meridians are called.

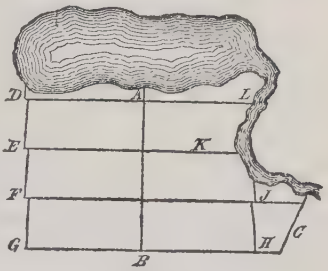


FIG. 7.

AB=Principal or Independent Meridian, and all the lines at right angles thereto Standard Parallels. The closing at *D* may be 23 chains, at *E* 20 chains, at *F* 18 chains east of the Guide and Standard corner, according to circumstances. The closing at *J* may be 20 chains west of the corner. *C* is a boundary line between two States, the river being a continuation of the line along its meanders, and in this case serving as a closing line for the surveys west of the stream and boundary.

Where these boundaries happen to divide different surveying districts, under the charge of two Surveyors-General, although one Principal Meridian may govern the lines in both districts, the boundary is frequently used to separate the two fields; and the surveys in each, though having a general reference to each other, are not connected.

Boundary closings are more appropriately dealt with in Irregularities, and the anomalies depicted in the illustration preceding, are also alluded to in the same place.

THE INDEPENDENT MERIDIAN.

An examination of the subject will show the necessity for again taking convergency of meridians into consideration. This time with respect to preventing the Checks from assuming rhom-

boidal shapes when platted, and arresting the tendency toward retrogression of the Guides belonging to the lower tier of checks in their relations to the higher series of Guide Meridians. This determination of the closing points toward the east in work west of a meridian, and the other peculiarities produced by allowing converged meridians to culminate in this manner, is exemplified in the annexed cut.

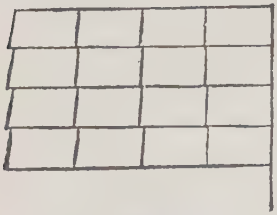


FIG. 8.

Referring these short meridians to a spherical figure, the subject is better illustrated.

Parallels of latitude being circles whose radii grow smaller from the equator toward the poles, it follows that a given distance measured along the higher circle of latitude will cross more lines of longitude than the same distance on a parallel nearer the equator.

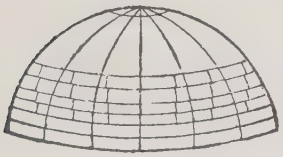


FIG. 9.

In North Latitude 49°, the twenty-first Guide Meridian Corner from a Principal Meridian would be six miles and eleven chains further west than the closing corner of the corresponding twenty-first Guide Meridian, running from the south toward the Standard or other parallel line from which the Guide first mentioned started.

It is not very often that the Independent Meridian is ordered into existence in a surveying district, as natural impediments to the accumulation of convergency "jogs" occur only too frequently, in the shape of boundary lines of various kinds, large reservations, navigable rivers, lakes, etc., to all or most of which the lines of public surveys close before any very great distance between the terminating and starting points of meridian lines can have appeared upon any one parallel line.

Still, exigencies will arise where it becomes desirable to introduce the Independent Meridian, arresting the "steps," and affording a new longitudinal base for further operations.

This is usually a guide meridian line produced indefinitely northward, starting from any convenient corner of guide and standard, shortening more and more the lengths of all parallels it may cross at right angles, the farther north it is prolonged.

An illustration of the effect produced upon the lines by the appearance of an Independent Meridian in the field is here given.

AB, representing the Independent Meridian, starting from the Guide corner *B*, cutting off the checks into smaller areas as it progresses. These interrupted lines form what are denominated fractional checks.

An arbitrary line of this description may be found requisite in a district for other than the reasons above given; but it is advisable, under all circumstances, to avoid their use if possible, the great number of fractional sections created by their presence rendering them specially objectionable.

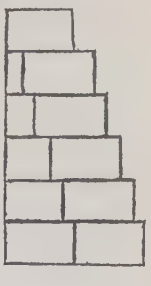


FIG. 10.

TOWNSHIP LINES.

Under this title is included all the true lines at six miles intervals inside the Check, whether running east and west, or north and south. The term township exterior being still more comprehensive, including generally all lines except sub-divisional.

Precisely speaking, the exterior *meridian* lines of a township are *Range*, and the *parallel* exteriors of townships are *Township* lines. The terms Ranges and Townships applying to the parallelogram of which the exterior lines form the boundaries.

The ranges, consisting of tiers of townships, are numbered from the principal meridian both ways; the first tier west of the meridian being Range 1 west, and the first tier east being Range 1 east, and so continued indefinitely.

The townships, consisting of a series of townships lying along a parallel, are numbered north or south of the principal base in the same manner.

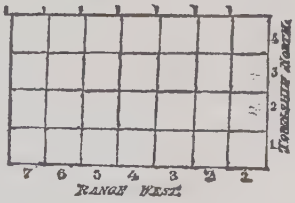


FIG. 11.

These numbers are not discontinued when the Check boundary is reached, but, regardless of jogs or interruptions, kept up through all districts, so far as it is possible, until the next principal meridian is reached, or until the lines projected from the adjoining principals are encountered.

The Check is divided into townships as follows:

Starting from the township corner to ranges 1 and 2 west of the meridian, township 1 north of the principal base, a straight line is run north six miles, marked at every half mile and mile with a quarter-section and section corner; the last corner being built somewhat larger than the others, as all corners at proper intervals of six miles are township corners, and so constructed.

Described in another manner: To commence the division of a Check into townships, a straight line is run north from the base at a point 6 miles west of the meridian. This line is continued up 6 miles, and the corner to townships 1 and 2 north, ranges 1 and 2 west, established. Township 1 north, range 1 west, is then inclosed upon three sides; namely, south by the base, east by the meridian, and west by the line between ranges 1 and 2 west.

From the last established corner (the corner to townships 1 and 2 north, ranges 1 and 2 west) a *random* or temporary line is run east six miles to the township corner on the meridian, 6 miles north of the initial point.

This temporary line seldom closes exactly at the corner, but must be made to do so by retracing the lines with a calculated course that will create a straight line of half mile and mile corners back to the starting-point, the temporary corners on line being destroyed, and permanent mounds built.

"Randoming" is treated of separately in this part. Although the temporary line has been thus made straight between corners, it is either longer or shorter than 6 miles; properly it should be short an amount corresponding to the effect of converged meridians. In Lat. 46° North, the north boundary of the township should be fully 75 links shorter than the south boundary of the same township.

There may, and do happen, instances, however, where the north boundary is slightly *longer* than the line on the south. This can be regarded as legitimate, and no correction made beyond throwing the difference over or under the 6 miles into the half-mile nearest the *western* boundary, the governmental limit for closings on township randoms being 3.50 chains, which is ample for all occasions.

Next, from the last township corner established, 6 miles west and 6 miles north of the principal lines, another township boundary or range line is run 6 miles north, and at its termination

another random line is run and retraced from the eastern to the western boundary and established as a true line.

This plan is persisted in until the north boundary of the Check has been reached, where the closing corner is built, and the distance measured and noted to the nearest standard parallel corner, as in guide meridian closings; the fractional deficiency or excess in length being similarly placed in the last or northernmost half-mile.

In endeavoring to make this matter explicit, the first line is run (from the corner 6 miles west of the initial point) 6 miles north, a true meridian line. Then 6 miles east a temporary or random line, which is retraced 6 miles west and established as a true line.

Then, from the corner regained by the retraced line, 6 miles north; thence east 6 miles and return, as before. Thence north 6 miles, and east 6 miles and return. Thence north 6 miles (more or less) to the Standard parallel, closing thereto.

The surveyor then returns to the principal base, and from the corner, 12 miles west of the initial point, carries up another tier of townships, closing as before, thrice to the east boundary of the tier and once to the standard parallel, carrying all fractional parts to the west boundary of the townships he is inclosing on the lines running east and west.

In this manner five tiers of the Check are established, and the *double*, or sixth and seventh tiers, remains to be run and the Check completed or townshiped. The double tier is perpetuated by starting from the base as in running other tiers, and, after retracing the line from the corner to the fifth and sixth tiers back to the corner to the sixth and seventh tiers, 6 miles north of the base, the random line for the seventh tier is then run *west* to the guide, then retraced eastwardly, leaving the fractional part of the line next the guide meridian.

First, north 6 miles a true line, thence east 6 miles a random line, which is retraced and made a true line.

Then, west 6 miles a random line to the guide, and retraced.

In this way the townships of the double tier are enclosed, and the process repeated by running the 6 miles northward, then the northern boundary of the eastern township, and afterwards the northern boundary of the western township. The third time this is done leaves the finishing line to be run north to the stand

ard and closed, and the Check is "townshiped" ready for subdivisions.

In a country where an obstacle prevents the extension and completion of township or range lines, the surveyor is referred to Irregularities and Expedients.

The Solar Compass is always used in townshiping, and, in addition to noting the topography on line, the variation of the needle must be noticed, and an account taken of its departure from the true north at every mile, or oftener, if there is an exhibition of local attraction.

Noting the variation at each mile is indispensable to the subdivision of the township; the subdivision lines being usually run with an ordinary open-sight compass.

TOWNSHIP RANDOM LINES.

When the first six miles of meridian line bounding the township upon the west has been run and marked as a true line, and the township corner established, the temporary or random line must be run from this corner, which we will designate as A, to the closing corner B. Many causes interpose to prevent the distance AB from equaling the length of the south boundary, in this case 6 miles, and very rarely will the random line end exactly at the corner B, usually falling within three chains or thereabouts north or south of B.

The random line is marked at every half mile and mile with temporary corners of any kind, and let us assume that in the case of the first random north of the base that the random intersects the east boundary of the township 75 links short of 6 miles, making the line 5 miles 79.25 chains long from A to B, and also encounters the closing line 56 links south of the closing corner B.

To convert this line into a true line by retracing from the corner B to close at A, the solar compass must be adjusted to an angle south 89° 56′ west, placed over the corner B, and the first quarter section nearest B on the temporary line destroyed, and rebuilt $51\frac{1}{3}$ links north, and 75 links west of its temporary place, making that corner just 40 chains, or half a mile from B.

The place for the next true section corner will be $46\frac{2}{3}$ links north and 75 links west of the location of the temporary corner which

is destroyed, as are all the random as fast as true corners are made.

The next quarter-section corner is moved 42 links north and 75 links west.

The second section corner $37\frac{1}{3}$ links north and 75 links west, next a quarter-section corner $32\frac{2}{3}$ links north and 75 links west.

The third section corner 28 links north and 75 links west, the following quarter-section corner $23\frac{1}{3}$ links north and 75 links west.

The fourth section corner $18\frac{2}{3}$ links north and 75 links west, the quarter-section corner 14 links north and 75 links west.

The fifth section corner $9\frac{1}{3}$ links north and 75 links west, the last quarter-section corner $4\frac{2}{3}$ links north and 75 links west.

The true line will then have five section corners with intermediate quarter-section corners at regular distances from each other, and the township corner, *B*, of 40 chains. The distance between the last quarter-section corner and the township corner *A* being 39.25 chains, constituting the fractional portion of that township.

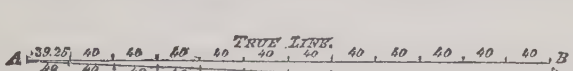


Fig. 12.

Had the closing of the random been 56 links north instead of south of *B*, the return course for the true line would have been *North* 89° 56′ West. Observe that where the closing line is intersected north of the corner, the course back is north, and where south the return course is south, so many degrees and minutes west, according to the departure.

For every 14 *links* departure from an exact closing on township randoms, *the rule is to allow* 1′ at the angle *A*, formed by the true and random lines, therefore the complement of that angle, 89° 59′, is used to retrace the line from *B*.

The solar compass being graduated on its horizontal plates to read by its vernier to single minutes of a degree, portions of closings within 14 links are used or neglected as the amount of the closing is nearer 14 or less than 7 links.

A closing of 14 links north or south of the corner requires a change of 1′ in the course = North or South 89° 59′ West.

28 links = 2′ = North or South 89° 58′ West.

140 links = 10′ = North or South 89° 50′ West.
257 links = 18′ = North or South 89° 42′ West.
350 links = 25′ = North or South 89° 35′ West.

Taking the last mentioned closing 3.50 chains, the following is the trigonometrical proof of the propriety of allowing 14 links to equal 1′ of arc in township random closings.

Base : R :: Perpendicular : tangent of angle at Base, from which we have $\frac{R \times A.B.}{B.C.}$ = Tang. of angle at C.

Fig. 13.

Taking $BC = 350$ links, $AB = 48000$. Then

$R = 10.000000$
Log $AB = 4.681241$
14.681241
Log $B.C. = 2.544068$
12.137173 = Log Tang. $ACB = 89° 34′ 56″$

The complement of the ascertained angle being within 4″ of 25′, the rule is proved as a very close approximation, which is all that is requisite when the verniers read only to single minutes.

The rule is sufficiently correct, for the same reason, if applied to lines 10 chains over or under 6 miles in length.

The foregoing is applicable to all random lines in townshiping, the only deviation being in the case of the double tier. The random line closing to the Guide meridian on the west boundary of the Check is run west, and the corrected return line east; consequently, to retrace those lines the course would be North or South 89° 35′ *East*, where the closing to the guide was 3.50 chains north or south of the corner. The fractional part of the line being nearest the guide, in correcting back no change of corners to the east is made, as the fractional half mile falls in its proper place in closing. The line, however, is to be moved north or south when necessary.

Passing obstacles by a trigonometrical operation while running the corrected line require that the course of the true line should be considered in connection with the triangulation, as the angles are modified by the course. See Triangulating, Part II.

SUBDIVISION LINES.

This species of work is the initiatory problem for the young surveyor.

The character of the field operations in subdividing a township, as revealed by the notes, is apt to be the criterion as to the ability of the surveyor to perform other kinds of work.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FIG. 14.

It is unimportant which township in a check has been selected for subdivision, but we will suppose that the one herein alluded to is Township 1 North, Range 1 West of the Principal Meridian.

There are 36 square miles or sections in a township, numbered as in the figure, always commencing with the northeast section, running the numbers west to 6, the next series below numbering east to 12, changing the direction in this way alternately, and ending with Section 36 in the southeast corner.

The method of subdividing resembles that of townshiping a check, in commencing with the line between Sections 35 and 36, running random lines east, and correcting west between section corners until the double tier is reached, then randoming west and correcting east.

The township exteriors and interiors are generally run by different surveyors, and the first step toward subdividing is to measure the east and south boundaries of Section 36. This is done to test the chaining, and to determine the variation of the needle, and see if any change in its departure has occurred since the line was originally established.

For instance, the variation is marked on the plat of the exterior lines opposite Section 36, as 12° 30′ east, which signifies that the needle, instead of pointing exactly north on that line, in reality points north 12° 30′ east.

The length of that line is also reported as 80 chains. Starting from the initial point, the vernier is turned off to 12° 30′ variation, and at 40 chains the quarter-section corner is found 35 links

east; continuing the blank or trial line to 80 chains from the initial point, the section corner on the meridian is found 70 links further east than the point of termination of the trial line.

The chaining is noted as coinciding, which is usually the case, but the variation has evidently changed 30′ since the meridian was established; consequently, to retrace this line, or run parallel to it, the magnetic needle compass must be adjusted to a variation of 13° east.

The adjustment of the compass is thus determined, to be used in running the true line between Sections 35 *and* 36.

Observe the variation marked on the plat for the south boundary of Section 36, and should it be found as 12° 25′ east, the south boundary being a true east and west course, the line is retraced from the initial point westward, the first quarter-section corner found at a place 25 links south of the point where 40 chains are run out on the trial line, and the section corner 50 links south of the 80th chain; to retrace or run parallel to this line the variation of the compass must be changed 22′ by subtracting it from 12° 25′ = 12° 3′ east.

Thus the adjustment of the compass for the random line between Sections 25 *and* 36 *is ascertained.*

Should the south boundary of the township be a corrected random line, the *course* of the line must be taken into consideration, with the variation, before retracing. As, where the variation is 12° 25′ east, and the course of the line north 89° 50′ west, 10′ must be taken from the variation, making it 12° 15′ east. From this take the amount found as the difference between the original and the present departure of the needle, and the variation becomes 11° 53′ east.

The method of quickly converting links of closing into minutes of course will be found in the part devoted to subdivisional random lines.

With the variation determined on the eastern boundary of Section 36, a true line is run north between Sections 35 and 36, a quarter section built at 40 and a section corner built at 80 chains. This corner is designated as the corner to Sections 25, 26, 35, and 36.

From thence a random line, with the variation as recently found on the south side of Section 36, is run east, intersecting the east boundary of the township either exactly at the corner

or to the north or south. The line is then retraced, the temporary quarter-section corner destroyed, and a true one built *midway* between the two corners.

From the corner to Sections 25, 26, 35, and 36, another true line is projected north one mile, with a variation created by the surveyor from the amount noted on the plat for the east side of Section 25, reduced or increased proportionately with the reduction or increase found in retracing the east side of Section 36, and also further reduced or increased as the line between Sections 25 and 36 is over or under 80 chains in length.

As an example, the old variation on the line bounding Section 36 was 12° 30′ east. It was found changed to 13° east.

Now, if the variation on the east side of Section 25 is set down at 12° 25′ east, it is fair to presume that a change of 30′ has also taken place on that line, raising it to 12° 55′ east, at which departure from the magnetic meridian it would be safe to run the line between Sections 25 and 26, unless the line between Sections 25 and 36 should be longer or shorter than 80 chains, in which case allowance must also be made in the variation of the line between 25 and 26, or the line between 24 and 25 will be still longer or shorter than its predecessor below.

Saying that the line between 25 and 36 measured only 79.30 chains, short by 70 links, this can be taken as evidence of local attraction on the line between Sections 35 and 36, necessitating the addition of 30′ to the variation of the line between sections 25 and 26, raising it to 13° 25′ east.

It is seldom that such great changes occur in variations, these being simply used as examples. Sometimes, however, townships are met with which have to be subdivided with a solar compass, the local attraction rendering the needle nearly useless.

When the random line between Sections 24 and 25 has been run it will probably close nearer 80 chains than in the previous instance, proving the variation on the true line between Sections 25 and 26 to be nearly correct.

In this manner the true lines and randoms are alternately run until the corner to Sections 1, 2, 11, and 12 has been reached, from which a random line north is run, intersecting the north boundary east or west of the corner, then retraced and corrected as a fractional section line, the excess or deficiency being left in the last half mile north.

The tiers of sections are carried up in the same manner from south to north, until the last two tiers, or "double tier," changes the direction of the westernmost randoms, as in townshiping.

A township bounded on the north by a standard parallel or base must be subdivided by closing the last section lines north, the lines between Sections 1 and 2, 2 and 3, 3 and 4, 4 and 5, 5 and 6, as *true lines* run from the south to the point where the standard or base is intersected, where a section corner is built with 3 pits, south, east, and west, and the closing distance measured to the nearest corner on the standard or base.

In establishing the interior lines of a township but little attention is paid to convergency; more frequently it is desirable that the lines should diverge from each other in endeavoring to create sections of 640 acres.

All sections, except those on the north and west boundaries, are sold by the government as containing 640 acres, regardless of the lengths of the east and west lines, although these should always be within one chain of 80 chains in length. The northern row and western tier of sections are classed as fractional, and the quarter sections bordering on the north and west boundaries are platted and sold as containing such areas as their measurements actually create.

In using the needle for subdividing, the following will be found a rule worth committing to memory, when a change in variation becomes necessary, and can be applied indiscriminately to true lines or randoms, regardless of direction:

If the closing line is intersected to the right of the corner the variation is too low, raise it; if to the left it is too high, lower it.

SUBDIVISIONAL RANDOM LINES.

Referring to the treatment of random lines in townshiping, we find that represents the temporary

Fig. 15.

course from A to C, the corrected course or true line from B to A; and the proportions

$$BC : R :: AB : \text{Tang. } C = \frac{R \times AB}{BC} = \text{Tang. angle } ACB,$$

besides the logarithmic formula, by dropping radius, which is here equal to unity, we have $\frac{A.B.}{B.C.}$ = Tang. angle at *C*. *Dividing the length of the line A.B. by the length of B.C. the quotient = Natural tangent of angle C* = course for true line.

Supposing that a random line from a section corner was run east, intersecting the north and south line at 79 chains, 70 links south of the closing corner, the course for the true line to be run west would be found by dividing 7900 links by 70 links= 112.857 natural tangent, 89° 30′. The return course would therefore be south 89° 30′ west.

The least troublesome plan is to divide the "closing," in the case just used 70, by 2, =35, which, reduced one-seventh=30′= complement of the course, 89° 30′.

Burt's rule for section random lines of nearly 80 chains is:

"*From half the number of links to be corrected in that distance, subtract one-seventh; the difference will be the number of minutes of a degree required for the correction of the course.*

"EXAMPLE:—Number of links to be corrected, 70÷2=35—5= 30′."

From the above can be deduced the rule for half mile corrections: Deduct one-seventh from the number of links closing, and the minutes of a degree for correcting the course is obtained.

For all other distances, the quickest method is to resort to Natural tangents, as just explained.

Taking another instance, should the random line running north to the boundary of the township, fifty-six chains, intersect the line twenty-eight links west of the closing corner,

5600÷28=200.=Nat. tangent. 89° 43′, or 17′ Nat. cotangent. Therefore the true line is south 17′ west.

Had this been upon a random line run east, and the intersection made south of the corner, the course would have been south 89° 43′ west.

If the closing was north, the return course would have been north 89° 43′ west.

A random line run west as in the double tier, requires that the return course should be east; if the intersection in such case was north, the return course would be north 89° 43′ east, if south, south 89° 43′ east.

In the first instance the north boundary of the township was supposed intersected west of the corner, the random line being run from south to north, and the return course south 17′ west. Had the intersection been east, the course would have been south 17′ east.

In taking account of topography, such as crossing streams, passing objects of noteworthy dimensions, etc., in subdividing, these are all recorded on the random line, whereas, in township-ing they are only mentioned in that portion of the notes relating to the true or corrected line.

Random lines through timber must not be blazed so as to leave any permanent marks. It may be convenient to bend or break the brush on a random course, but this should be done at right angles to the random. The true line is blazed back (See Blazing, Part III.), and brush or small saplings are bent, broken, or cut in the direction of the line.

The east and west random lines should close within one chain of the length of the line running parallel to it one mile south, except the randoms closing to the west boundary of the township.

Lines closing to the north or west boundaries can fall within any reasonable length proportioned to the lengths of the including exterior boundaries, as all differences in chaining or variation are intended to be brought up to those boundaries. A difference of one chain between two parallel lines will generally be found ample limits, though in fact no limit is given.

SUBDIVIDING INTO QUARTER SECTIONS.

The section to be quartered should first have its exterior lines carefully re-run and measured, and with a variation intermediate between those of the two boundaries north and south, a line run from the quarter-section corner on the west boundary to the one on the east.

The line should be retraced as in subdividing into sections, and the quarter-section corner placed in the centre of the section.

The object to be kept in view is to divide the contents of the section, whatever they may be, proportionately.

Fractional sections are divided by first measuring and noting the length of the exterior lines, then, with the mean or propor-

tionate variation, run a course through the centre, toward an exterior quarter-section corner, correcting back as in other subdivisions.

Where a section has been made fractional by a lake, reservation, or similar cause, the intermediate course is run, and this line is not retraced, but established as the true line.

Great accuracy could be attained by running lines at right angles to each other through the section, and by so doing, determining the precise centre of the section.

It is rarely required of government surveyors to perform this kind of work, as it properly pertains to the County Surveyor.

MEANDERING.

When true lines encounter a navigable stream or lake of forty or more acres, or a body of water forming a boundary line between States, Territories, and sometimes districts, meander corners are built, and, if the lines are extended across the obstacle, meander corners are also constructed at the point of leaving, on line.

From one of these corners courses and distances are determined, forming a meandered line upon a side of the obstacle, extending to the next meander corner, from which further meanders are projected until the entire shape of the river or lake is ascertained.

The surveyor must use judgment in not running these lines too close nor yet too far from the water's edge, the proper confines of the water being the object to be ascertained by the meander.

Circumstances must guide the survey of these boundaries as to the location of the starting-point, direction, etc., but preferably the southern and eastern meander corner, and the one upon the township line, when surveying west of the meridian, is generally the starting-point, and the line meandered from south to north.

Meanders are only made while subdividing, and, after the township has been finished in other respects, the meandering is commenced.

If a lake of forty or more acres falls within a section and is not crossed by any regular line, a blank line should be measured north, south, east, or west from the nearest corner of the section exterior along the section line, far enough to enable a blank

starting-point to be found, from which a line at right angles to the section line will intersect the object to be meandered.

A base line, also blank, is measured from the starting-point to the water's edge, where a meander corner is built. A similar line is run opposite in a different direction toward the same object, and another meander corner built on the other side of the pond or lake.

Fig. 16.

From one of these corners the meander line is run closing to the second, and thence to the beginning.

Fig. 16 illustrates a line crossing a lake from *A* to *B*. Starting from *A*, the bearing to *b* is taken, and the distance measured, then the compass is moved to *b*, and the course and distance to *c* taken, thence to *d*, and so on until *B*, the opposite meander corner, is met, when the course and distance from *p* to *B*, closes the meander of that bank.

Fig. 17 shows the meanders of a lake lying wholly within a section.

A base line is measured from the northern and southern quarter-section corners to *a* and *b*, and the meanders commencing at *a* are run around the lake to *b*, and thence to *a*.

Fig. 17.

Had the lake been otherwise than opposite a quarter-section corner, the base line could have been started from any point on the exterior lines, at any distance between the section and quarter-section corners. These distances are noted with the other details, so that the relative positions of the exterior lines and the lake may be accurately platted as well as the meanders of the lake. Traverse tables being generally calculated to 15′ angles, it is advisable to make meander courses read to quarter degrees instead of intermediate minutes, except in closing, or where an extreme length of a side of the lake falls in one course.

Similarly, for convenience in platting, it is best to make all distances even chains except the closing line, and when inconvenient to do so, use tenths of a chain. This will facilitate rapid protracting and computations in the office.

To meander islands crossed by government lines, meander

corners are previously established at opposite points on the shore of the island, and the meanders run therefrom as for a lake.

Should the island not be crossed by a line, measure a special base from the nearest meander corner to the island, triangulating to and establishing at any convenient place on the island a special meander corner, from and to which the meanders of such island start and close.

Meander lines are not marked or blazed, but topography is noted thereon as upon other lines.

In field notes, the right and left banks of a stream are those banks to your right or left facing down stream.

Both banks of navigable streams are meandered; but only that portion falling within the work of the deputy is to be meandered by such deputy.

Rivers not navigable are sometimes to be meandered upon one bank only, if of any geographical importance, and where they have an uniform width. When this is ordered to be done, the right bank is meandered. Should the left bank be found more convenient to work upon, the sides may be changed, but only from a meander corner.

The deputies who subdivide the sections through which such stream passes, must establish meander corners at all intersections of the lines with the stream, similar corners being placed at the crossings of township and other lines.

Lakes containing a less area than 40 acres; long, narrow, or irregular lakes, less than 80 acres; shallow bodies of water liable to dry up; marshes, or sloughs, of whatsoever extent, should not be meandered.

Errors in closing of 150 links are disregarded when the work is completed. (See Traversing Meanders.)

IRREGULARITIES AND EXPEDIENTS.

L'homme propose, et Dieu dispose. There are many impediments preventing the application in the field of the unique system of surveying adopted by the government.

In Figure 7, the portions of the standards *H* and *J* are closed to the boundary line *C*, and the lines *K* and *L* and the guide running north from *J* are stopped by the stream. These are instances of the prolongation of lines being arrested by obstacles.

Frequently, in running township or sub-division lines, a departure from the regular order of surveying is necessary; an example being here given. In this case, a township has been made fractional by the presence of a lake and boundary line.

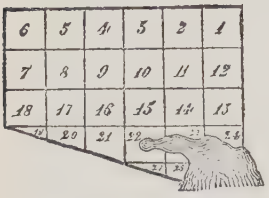


FIG. 18.

The eastern boundary of the township is run a true line from the northeast corner, establishing corners at every 40 and 80 chains, closing with a meander corner on the north bank of the lake, the fractional part of the line being in the last half mile next the lake.

The western boundary is run in the same way, closing to the reservation boundary, by starting from the northwest corner of the township and running south, also throwing the fractional part next the reservation. In this instance, we have the west side of the township 240 chains long, leaving no fractional part on that line.

A line may then be run, as in township randoms, between Sections 18 and 19, 17 and 20, 16 and 21, 15 and 22, 14 and 23, 13 and 24, and retraced, throwing the fractional part next the west boundary of the township. From this line as a base, true lines are run south toward the lake and reservation, closing thereto with meander corners on the bank of the lake, and closing corners, with three pits, one on each line, at the intersection of the subdivision and reservation lines.

From the corner to Sections 21, 22, and 27 a true line is run east between Sections 22 and 27, 23 and 26, closing to the lake with meander corners, and lines run north and south from the corner to Sections 22, 23, 26, and 27, closing north to the lake and south to the reservation, as before.

From these meander corners the lake is meandered, commencing at the meander corner on the reservation line and closing finally to the township meander corner.

The subdivision of the remaining part of the township into 18 sections is accomplished in the usual manner. From this simple explanation may be constructed many forms of irregularities liable to be encountered in actual operations, the intelligent surveyor not needing instructions *how* to perform the work so much

as he requires information upon what to do and what would be admissible in the field notes.

There may be instances where it will become necessary to reverse operations, and commence subdividing a township on the western side, between Sections 31 and 32. When a township is made fractional by having its eastern tier of sections fall in a lake or cut off by a reservation, etc., this may occur.

Sometimes it may be required to run from the northern boundary of the township, running true lines south, omitting the northern and, if need be, the western tiers of fractional sections, making all sections full 640 acres, except those bordering on the object causing the change.

It may even happen that but a few acres, or part of an acre, constitutes all that is left of a township made fractional by boundaries or lakes. Such pieces of land receive their appropriate section-number, the same as though they had belonged to a full township. Should there be an Indian or military reservation or an old land grant, similar to those given by the Spanish Government to individuals or corporations, or any other parcel of land through which government lines are not to be marked, it will be necessary to have corners or mile-posts on such lines, to enable the closing distances of the government lines to be ascertained. This will occasionally render it necessary for the deputy to resurvey the exterior lines of the obstacle, and mark, in a manner intelligible to himself, at least, each mile of the entire course, for which service he will not be paid by the government, it being presumed in such cases that the reservation exteriors had been previously properly marked. The department, however, allows pay for the chaining necessary in measuring from closing corners to the mile or half-mile posts of the reservation exteriors.

If but a small part of an obstacle of this description is projected into the deputy's work, a *blank* line may be measured across, and closing corners built both upon entering and leaving the reservation. Random lines may be in this way carried through and retraced, when possible.

When, for any reason, as among mountains, it is desirable to survey a township remote from principal lines, the standard parallels and guide meridians, or a standard and guide, or independent meridian, must be brought from the nearest principal

base or meridian, to enable the township to be connected with all subsequent work, in its proper place. This produces a variety of departures from the ordinary course of things, by requiring all standards, guides, and township lines to be run in its vicinity in directions closing to the independent work mentioned.

The question of irregularities in field operations involves such a great and intricate number of expedients that any explanation beyond what is already given would serve more to confuse than enlighten; and by remembering that the chief objects of governmental surveying are to preserve uniformity of areas as far as practicable, and to accurately settle all questions of locality, the subject of how this can best be done becomes the deputy's mathematical problem, and a matter to be determined by circumstances and the decision of the Surveyor-General, acting under the advice of his chief clerk, or often under special advices from Washington.

Offsets should be considered in this connection as an important expedient, when it is proper and convenient to use them.

It would evidently be unnecessary to triangulate over an obstacle when an offset could be used, and, except with instruments seldom made use of by deputies, these should consist of but two kinds; the right angled and oblique angled offsets: and then, upon reaching the opposite side of the object passed the line should be verified, when practicable, by back sighting.

It may become necessary in bends of rivers skirted with dense forests and among marshes to run meandered lines to establish corners or lines, but much care must be used, and a traverse calculated as the locality is reached, to enable the surveyor to make the final angles and distance accurate; a re-meander to the starting-point is the verification, unless the main line is visible from the part so determined.

PART II.

TRIANGULATIONS.

THE base line should be *carefully* measured. When it is remembered that errors in the base are not only reproduced, but magnified in the distance, it is evident that too much care cannot be exercised in measurement.

By RIGHT ANGLES, distances across lakes, rivers, etc., may be found by turning off a base line at right angles to the line which is being run, as AC, and from the point C the angular bearing of B is read, and by Natural Tangents the distance AB found.

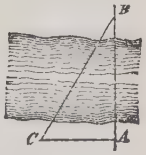


FIG. 19.

Radius : Base :: Tangent angle at base : Distance AB,

and $$\frac{AC \times \text{Tang. } C}{1} = \text{Distance } AB;$$

hence, *by multiplying the natural tangent of the angle at C by the length of the base line AC, the distance is ascertained from A to B.*

By Logarithms : Log tang. C + log AC − log R = log distance AB.

Taking $AC = 10$ chains, and angle $C = 50° 10'$, we have

Log tang. C	=	10.078753
+ log AC	=	1.000000
= log AB		1.078753 = Distance 11.99 chains.

The natural tangent process is equally quick and accurate.

Extend the base line either in the same or an opposite direction, take another observation, and the mean of the two answers will be the correct distance.

The distance BA is also found by taking the angle at B with the bearing of C, AC being known, multiplying the natural cotangent of B by base AC.

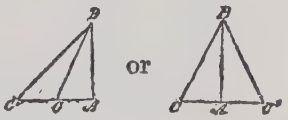


FIG. 20.

Without tables the distance may be found by measuring AB',

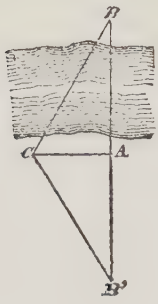


FIG. 21.

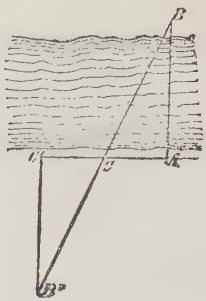


FIG. 22.

found by first observing the angle ACB, and setting off a similar angle ACB'.

Another method is with the base AC' (Fig. 22), bisected at C, take the bearing of B from C, produced to B' on shore, and the length of $C'B'$ by measurement will equal AB.

The use of natural tangents, and even logarithms, will be found a more rapid and easier process, and in some respects less liable to errors.

FIG. 23.

By OBLIQUE ANGLES.—Sometimes useful, when, from the nature of the ground, right angles cannot be conveniently taken. In Fig. 23 we have the angles A and C [from which the angle B is found by its being the supplement of the sum of the other angles,] and the side AC the base line.

$$\text{Sin } B : AC :: \sin C : AB = \frac{AC \times \sin C}{\sin B} = AB.$$

For instance, let $AC = 28.16$ chains, Angle A, 49° 25′, Angle $C = 63°\ 48'$, to find the distance AB.

49° 25′ + 63° 48′ = 113° 13′, which, taken from 180° = 66° 47′, Angle B. Then

Log AC 28.16	1.449633
+ Log sin C 63° 48′	9.952918
+ Co-log sin B 66° 47′	.036675
= Log AB	1.439226 = 27.50 Distance.

There may arise opportunities requiring different applications

of trigonometry, but the foregoing will be found useful in the majority of cases.

The surveyor should not resort to the Traverse table in triangulating, as every minute of the angles should be used, and with that table all parts of arc between 15′ are discarded.

Always use a base at least one-fourth the distance, by estimation, if practicable.

On randoms, in subdividing, the lines bearing to the cardinal points will cause all triangulations to be made with reference to either a north, south, east, or west course, and as topography is noted upon the random lines in the notes, the ascertained distance will always be upon the meridian or a parallel of latitude; but in townshiping, the topography is recorded on the corrected or true course; therefore triangulations must be made with regard to the course of the lines in such cases. As, should it be necessary to use trigonometry in ascertaining the distance AB, when the line AB runs south 89° 50′ west, the field notes must not show that the deputy "caused the flag to be stationed due east or west on the opposite shore," nor must he run his base line north or south from such a course, expecting such base to be at right angles to the line.

A base to be at right angles to a course south 89° 50′ west, should be run north 10′ west, or south 10′ east, and the bearing of all other angles should be modified by the course.

TRAVERSING MEANDERS.

Just as the discrepancies in magnetic variation create the need of corrected courses in subdividing, so will meandering require some test and method of correction to reduce them to proper connections between meander corners.

This may be done by protracting, and thus solving the matter instrumentally by means of a table of chords, or protractor and scale of equal parts, or by the better operation of traversing.

To explain this matter, resort is made to the annexed cut.

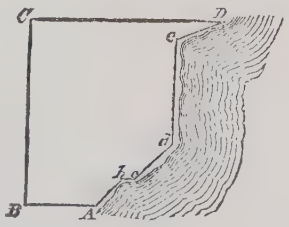


FIG. 24.

A and D are meander corners built upon the river bank. B and C are section corners.

TABULATING THE DIFFERENT COURSES.

			CHAINS.	
1.	*A* to *b*,	North 25° 15′ E.,	15.00	From meander corner.
2.	*b* to *c*,	East,	3.00	
3.	*c* to *d*,	N. 50° E.,	20.00	
4.	*d* to *e*,	North,	46.00	
5.	*e* to *D*,	N. 70° 45′ E.,	23.00	To meander corner.
6.	*D* to *C*,	West,	78.00	To section corner.
7.	*C* to *B*,	South,	80.00	To section corner.
8	*B* to *A*,	East,	31.50	To meander corner.

The traverse operation results in finding how much each course and distance bears north, south, east, or west, as follows:

	LATITUDE.		DEPARTURE.	
	N.	S.	E.	W.
1.	13.56		6.39	
2.			3.00	
3.	12.85		15.32	
4.	46.00			
5.	7.57		21.73	
6.				78.00
7.		80.00		
8.			31.50	
	79.98	80.00	77.94	78.00

Had the Survey and Traverse been exact, the sum of the northings would have equalled the sum of the southings, and the eastings the westings, but the closing limits between meander corners being 1.50 chains, the errors of 2 links in northings and 6 links in eastings are not to be regarded.

To traverse a field it is necessary to commence at the first corner, setting down the courses and distances of all meanders and lines around the field, ending with the starting-point.

Then from the Traverse table take the latitudes and departures corresponding to the bearings and distances, observing that lines bearing more toward the north than east require the larger number of chains to be placed under the heading North; and, *vice versa*, lines bearing more to the south than west require the larger number under the heading South, and so on.

Add together the northings, which should agree with the south-

ings, and add the eastings, which should correspond with the sum of the westings.

The meanders of an island or lake entirely within a section, are traversed in the same manner from a meander corner back to the same corner.

ASTRONOMY USED IN SURVEYING.

REFRACTION is a distortion of the rays of light in passing through media of different densities, and is a matter requiring consideration in the use of all astronomical instruments proper.

It can be best exemplified by nearly filling a basin with water and holding a straight stick therein, at various angles of inclination. Held perpendicularly in the water, no change is observed in the appearance of the stick ; but incline it in the least, and the part in the water seems bent from the portion out of the water. The nearer horizontally the stick reclines in the water, the greater will be the angle of refraction between the immersed and dry parts.

Atmospheric refraction has a similar effect upon the apparent positions of celestial bodies, bending the rays emerging or reflected from them upward toward the zenith.

When the sun, or any other luminary, is in the horizon, its apparent displacement from this cause is enormous, so much so, that when the sun has actually set it remains still visible above the horizon. The amount of refraction decreases from the horizon to the zenith in an almost regular proportion (See table), and, so far as the solar compass is concerned, can be considered as a constant quantity, for each degree of altitude.

In the zenith there is no refraction ; at 45° elevation it amounts to 57″ and in the horizon 33′.

So rapidly does refraction differ at different altitudes, the sun and moon present oval appearances, due to the unequal refraction of the lower and upper limbs, " the effect being to bring the two limbs apparently closer together by the difference of the two refractions."

Sir J. Herschel says Claudius Ptolemy was the first to discover the effects produced by refraction, during the first century.

In reducing apparent to true phenomena, refraction is to be

subtracted, and, in use with the solar compass, it is always added to the true altitude in calculating apparent positions.

When the barometer rises, the air grows denser and changes the value of the angle of refraction by increasing it. A depression of the thermometer creates a similar change; but the surveyor will not have occasion to make these corrections in using the solar compass, because these differences occur in augmented forms when the sun is very low in the horizon only, and at a time when the solar is seldom used; or if lines are being run during the hours of sunrise or sunset, the refraction changes so rapidly as to defy being allowed for, except approximately, below the equatorial lines, and at these times it is safer to rely principally upon back sights.

Horizon.—The visible, or, as it is technically termed, the *sensible horizon* is confined to a radius of a few miles, in the most favorable locations on the earth's surface, but the *rational horizon* extends 90° in all directions below the point of observation.

This should be well understood.

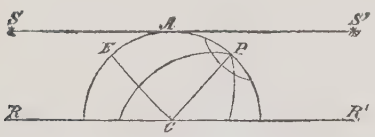


Fig. 25.

S and S' represent the Sensible, R and R' the Rational Horizon, P the Pole, E the Equator.

An observer stationed at A in north latitude can see only those terrestrial objects confined to his terrestrial visible horizon, such as trees, houses, etc.; but taking celestial objects many million miles distant, the effect produced is similar to reducing the earth to a mere speck, rendering those objects visible upon all sides, except when hidden from view by the opaque earth. The field of view is by this comparison changed from A to C, the center of the earth, enabling observations upon such bodies as the sun, planets, and fixed stars to be made at *nearly* the same visual angles from either A or C. Nearly, because parallax should be considered in the change; but as that has so very small an effect upon the parallelism of lines extending from C and A to the bodies mentioned, so far as the solar compass is concerned parallax need have but little consideration.

PARALLAX is the difference between the apparent angles of altitude of a celestial body as observed from the earth's surface, and center. Solar Horizontal Parallax is the angular semi-diameter of the earth as seen from the sun.

The nearness of the moon to the earth would necessitate a correction for parallax, but, in surveying, the moon cannot be used to any advantage, consequently it cannot be connected with the matter in hand.

The solar horizontal parallax is a constant quantity, or can be so considered in surveying, and amounts to 8″.94 in the horizon, and nothing in the zenith, always having an opposite effect to refraction, therefore subtractive from true altitudes in ascertaining apparent altitudes.

For example: if the true altitude of the sun is 45°, the refraction increases its apparent altitude to 45° 0′ 57″ which parallax reduces to 45° 0′ 51″.

A government surveyor is rarely found who considers parallax of any consequence, and some entirely disregard refraction, but these cannot be said to have mastered the business.

DECLINATION is the angular distance of the sun, planets, etc., from the equator, as seen from the earth's center, and is counted north or south.

In summer the sun is north and in winter south of the equator. During the vernal and autumnal equinoxes the sun is over the equator, and is said to be "crossing the line." During the summer solstice the sun has attained its greatest distance north, and at the time of the winter solstice its greatest distance south of the equator.

These departures are confined to the ecliptic, and in the case of the sun do not exceed 23° 28′ north or south.

LATITUDE Parallels are circles parallel with the equator at any distance north or south of the equator.

Degrees of latitude are circles environing the earth at nearly equal distances, averaging 69 miles apart, varying in length according to the rotundity or oblateness of those zones which they inclose.

Differences in the lengths of a meridian line between two parallels of latitude near the poles, and two near the equator, are too small to exert any perceptible influence in the use of the solar compass, but for the benefit of those who desire accuracy, a

table of lengths of the meridians, in various latitudes, is inserted, with the more important dimensions, in various latitudes, of degrees of longitude.

There is an appreciable difficulty in running parallels of latitude, explained under Convergency, and incidentally in many other places in this book, a proper consideration of which would guard deputies from many "bad closings," and similar vexations.

LONGITUDE is very generally reckoned east and west from Greenwich, England. The American Ephemeris counts all longitudes from that place in the principal parts, for the use of navigators and surveyors. In all latitudes a difference of a degree of longitude is equal to a difference of 4 minutes in time, therefore, 1′ longitude = 4 seconds, and 1″ of longitude = $\frac{1}{15}$th second.

1 second of time = 15″ longitude, 1 minute = 15′, 1 hour = 15°. To convert longitude into time multiply the minutes of longitude by 4, and the result is seconds of time. To change time into longitude multiply the seconds of time by 15, the result is seconds of longitude.

Meridians of longitude are not parallel to each other, at the equator the distance apart being 69.163 miles; and, all meridians meeting at the poles, intermediate places give varying lengths, according to their proximity to equator or poles.

When it is noon on the meridian of Greenwich it is 5 h. 33 m. 58 s. A.M., in longitude 96° 30′ 30″, and 6 h. 26 m. 2 s. P.M., in Greenwich, is noon in the longitude mentioned.

APPARENT ALTITUDE in the meridian is computed by adding algebraically the declination of the sun to the co-latitude of the place of observation, adding also the refraction corresponding to the elevation, and subtracting parallax.

It has been already explained, that so far as the sun was concerned, observations from the points Z and C would be identical. H being the rational horizon, altitudes from Z are referable to the station C and horizon H, Z becoming the zenith.

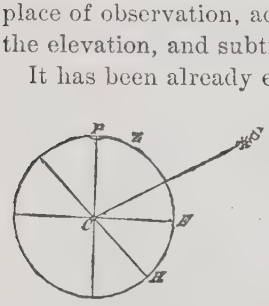


FIG. 26.

P being the north pole and Z to H being 90°, calling Z north latitude 47° = distance from the equator,

then from E to H must equal the complement of 47°, polar distance of Z, or co-latitude of the place of observation.

If the sun, S, is in 20° North declination, to ascertain its meridional altitude above Z, take $SCE = 20° + ECH = 43° = SCH = 63°$ = approximate altitude.

The refraction for 63° added and parallax subtracted, gives the apparent altitude.

If S is between E and H, subtract SCE from ECH, which is the case when the sun is south of the equator.

Explanation of altitudes out of the meridian involves the use of spherical trigonometry.

The principal use of an altitude of the sun in solar compass practice consists in determining by its means the amount of meridional refraction necessary to be turned off on the declination arc.

Apparent altitudes of the sun may be taken at any time or distance of the sun from the meridian, with a sextant or solar compass, from which, clearing the observation of index error, refraction, and parallax, the true altitude may be deduced.

Parallax correction is found by multiplying the solar parallax by the co-sine of the observed altitude.

With the sextant, the corrections in ascertaining altitude are, in addition to those mentioned, for semi-diameter and dip, the former always applied and the latter used at sea. Where the artificial horizon is used, the angle is simply doubled, and the apparent altitude obtained by taking one half the amount.

Equation of Time. The following explanation is from Chambers' "Chronological Astronomy:"

"The clocks we have in common use are all regulated to mean time, and will therefore show 12 o'clock sometimes before, and sometimes after, the true sun has reached the meridian; this difference between mean and apparent time is called the equation of time, and tables are constructed for the purpose of reducing the one to the other. Four times a year the correction is zero, and the true and imaginary suns coincide. Twice in the same period the clock is before the sun and twice after it. The equation reaches its maximum about February 10th, when a correction of about 14 m. 32 s. is required to reduce apparent to mean solar time; or, in other words, the mean sun is on the meridian 14 m. 32 s. before the true sun. On April 15th there

is no equation, the real and fictitious suns being on the meridian at the same moment. Toward the middle of May, the equation again reaches the maximum of 3 m. 54 s., but becomes reduced to zero by June 15th. Another maximum occurs about July 27th, when a correction of 6 m. 11 s. is required to be added to the apparent solar time. On September 1st, the equation is again at zero, but increases from that time until the beginning of November, when the correction amounts to 16 m. 17 s., subtractive from apparent time. Another zero takes place about December 25th, completing the circuit."

The equation table to convert apparent into mean time will be found among the other tables in Part IV.

Magnetic Variation. The needle does not point north except in a few localities on the earth's surface, and in no place does it continue to point to any given angular distance from the north, changing secularly, annually, diurnally, and hourly, and is, further, subject to fluctuations reducible to no method of tabulation; and in the vicinity of iron in any shape, or magnetic sands, the needle is deflected toward the material attracting it. This perturbation is known as local attraction. The author has known the needle to vary 5° in a distance of one mile, and 1° 30′ during two hours when stationed in one place. These are not frequent occurrences, but go to prove the instability of the instrument, and its unfitness for accurate surveying on all occasions.

Where local attraction does not exist, tolerably good lines may be run with a needle compass.

The variation of the needle from the true north is determined by the surveyors who run the exterior lines of townships with Burt's Solar Compass, and when the needle is used, variations corresponding to those upon the nearest exterior line are used in subdividing; consequently, we need not explain here the numerous methods used in finding the variation, beyond mentioning that the quickest plan is to read the amount direct from a solar, when required.

The variation is in some places in the United States east, and in others west.

In Dakota, the average variation is 12° 30′ E.; in Minnesota, about 11° E.; in Montana, 20° E.

According to Henck, the variations in Maine are 10° to 15°

W.; New York, 5° to 12° W.; Pennsylvania, 0° to 5° W.; Delaware, 2° to 4° W.; District of Columbia, 1° to 2° W.; Virginia, 6′ to 39′ W. and 2° E.; Florida, 4° to 6° E.; Mississippi and Texas, 7° to 9° E.; Ohio, 1° to 5° E.; Tennessee, 7° E.; Michigan, 2° E.; Indiana, 4° E.; Missouri, 9° E.; Wisconsin, 7° to 9° E.; Iowa, 7° to 10° E.; California, 12° to 16° E.; Oregon, 18° to 20° E.; Washington Territory, 21° 30′ E.; Eastern Hemisphere, 10° E. to 30° W.

The existence of local attraction can be discovered, and to some extent counterbalanced, by back-sighting, and thus keeping the line straight; but should the vicinity of the starting-point be troubled in this way, the surveyor will not be apt to discover the difference until toward the close of that line, or unless he should have, before starting, observed his starting course to be at the proper angle with the line from which he started.

USES OF LOGARITHMIC AND OTHER TABLES.

To find the logarithm of any number seek the number in the left hand column marked No., and against it in the column marked 0 will be found the decimal part of its logarithm. To this number affix the characteristic, always one less than the number of integral figures in the number.

If the number consists of four figures, the first three are found in the left hand column, and the other at the head of one of the other columns. Opposite the first three numbers, and in the column under the fourth, will be found the figures of the decimal part of a logarithm, to which prefix the characteristic.

Thus, the logarithm of 3456. is 3.538574; the logarithm of 345.6 would therefore be 2.538574, and 34.56 would be 1.538574.

When the number has more than four figures proceed as before for the first four, and the proportional part for the fifth figure will be found in the column headed Diff. So, when the tabular difference is 120, the corrections for 1, 2, 3, 4 in the fifth place are 12, 24, 36, 48.

If the given number was 72501, the characteristic would be 4 and the logarithm 4.860344.

The table of logarithmic functions is used by finding the degree of the quadrant at the top of one of the pages, and the minutes in the left hand corner. Opposite the minutes the loga-

rithm will be found, and in the next column the proportional difference for quantities less than one minute.

If the arc is 45°, or greater, it will be found at the bottom of the page, and the minutes in the right hand column.

The Traverse table is used by taking the angle from the top or bottom of the page and the distance from either side. Should the distance exceed 50, multiply or add to the latitudes and departures accordingly.

The table of natural tangents have the degrees at the top and minutes at the left hand side, the cotangents have the degrees at the bottom and minutes at the right hand side, reading upwards.

The table of Convergencies in the column next to the latitudes gives the closings of a Guide Meridian 24 miles in length, when the standard parallel is 42 miles long. The next column shows as far as north latitude 35° the closings for the 30 by 48 miles check. The third column gives the closing of a tier of townships 6 miles wide, and 24 miles long. The fourth column contains the convergencies of townships situated next the parallels, in the various latitudes. For other closings these distances may be taken as proportional. For instance, if a township in latitude 25° north closes 34 links short of 6 miles, the next line 6 miles north would be 68 links, the next 102 links, and the last 136 links less than 6 miles in length.

The next three columns are arranged for correction angles to the nearest minute of a degree adapted to back-sighting either the standards of 42 and 48 miles, or the township line of 6 miles. The angle of convergency formed by the closing of the guide to the standard is given in the next column.

The lengths in arc of a mile of the meridian in various latitudes will be found in the first column of Lengths, and this, with the number of minutes, seconds, and fractional parts of a second, in 6 miles of the meridian in the following column, will be found of frequent use.

The last column gives the number of miles in a degree of longitude in the different degrees of latitude.

The refractions for altitudes and the equation of time complete the list of tables.

VERNIER READING.

Peter Vernier, a Frenchman living about A.D. 1630, invented the Vernier, which is frequently improperly confounded with the Nonius, an invention of a Portuguese named Nuñez, who died A.D. 1577.

A Vernier is an appliance for reading smaller portions of arc or measurement than are graduated upon the scale to which it is attached.

The arc may be graduated to half degrees from 0° to 90°, etc., and the vernier is divided into 30 equal parts, each one being one-thirtieth shorter than a space of the arc, the 30 spaces on the vernier coinciding with 29 of the arc.

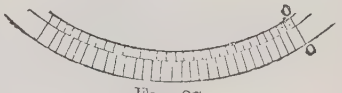


FIG. 27.

The spaces on the arc being 30′, 29 of which are equal to 30 graduations of the vernier, it follows that each of the vernier spaces is one minute shorter than a corresponding space in the arc.

When the zero on the vernier coincides with a line on the arc, the scale is read to degrees, or half degrees. If the first line beyond 0 of the vernier is opposite the first on the arc, the reading is 1′, the fifth lines agreeing the reading is 5′, etc.

The vernier enables the ordinary magnetic needle compass, the declination, latitude, horizontal, and needle arcs of the solar compass to be read to single minutes, and a more extended application of the principle enables the sextant to be read to 10″ intervals.

CONVERGENCY AND DIVERGENCY.

All meridian lines converge towards each other, meeting at the poles, and diverge from one another in running south, causing inequalities in the lengths of degrees of longitude at various latitudes. Hence, meridian lines are not parallel to each other.

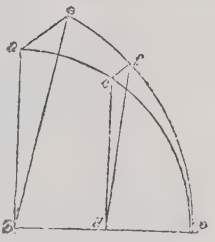


FIG. 27.

Differences of lengths of parts of longitude are found in this manner:

Cos lat. given place, *a* : cos lat. another place, *c* : : length of one portion of longitude, *ae* : length of another portion of longitude, *cf*.

Subtract the lesser from the greater length of longitude and the remainder is the difference arising from convergency, increasing as the lines are run from *a* to *P*, *bdP* being the semi-diameter of the earth.

Surveyors are generally aware that an east and west line cannot be backsighted, and this question of convergency involves the explanation.

With an instrument adjusted at right angles to the plane of the meridian, so far as that spot is concerned the sights will be east and west, but, parallels being curved lines, by prolongation the instrument is in reality pointed on both sides towards the equator. The determination of the angle of correction for a parallel backsighted line would be to ascertain the difference of closing or amount of convergency, *ab*, where the lines, *ac* and *de* (Fig. 29) were of equal lengths.

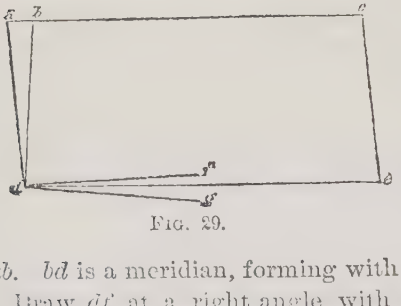


Fig. 29.

ce is a meridian line to which *ad* is parallel, and, consequently, *ad* is not a meridian line, as it diverges therefrom by the difference *ab*. *bd* is a meridian, forming with *ad* the angle *adb*.

Draw *df* at a right angle with *ad*, then take *dg* at a right angle with *bd*, then, by construction, *de*, the chord of latitude, bisects the angle, *fdg*.

Therefore, Burt's rule is: "*When running a parallel of latitude, if an object be observed due east or west from any station, the correction of the course to touch the same parallel in the meridian of the object is equal to one-half of the angle of convergency between the two meridians, which pass through the station and the object.*"

In practice this accounts for taking one-half the difference between fore and back sights, and setting it off toward the pole for sighting a true parallel line.

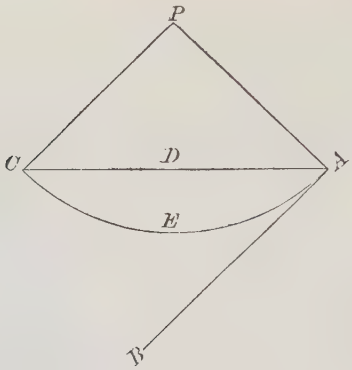
Or, the angle to start a line of sights, on an east and west line, is equal to one-half the angle of convergency.

The formula for ascertaining the convergency, applied to government work either for a township or check, becomes:

Cos lat. of south boundary . cos lat. of north boundary : : length of south boundary : length of north boundary.

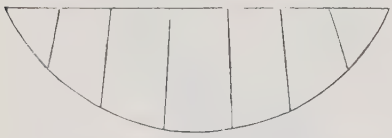
Given the south, east, and west boundaries of a check, the lati-

CORRECTION ANGLES ILLUSTRATED.

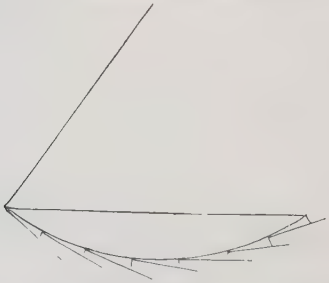


P, North Pole.
ADC, Sighting Chord.
A and *C*, Stations.
AEC, Parallel of Latitude.
AB, Tangent.

With *A P* and *C P* as meridians, the station *C* would be observed an angular amount North of West of *A B*, the apparent and *A E* the true parallel, from the station *A* depending upon the latitude of that station.



When running Standard Parallels the correction offsets can be used from each corner on the sighted line southward to proper corners on the parallel, or the correction angle for six miles may be



taken and set off from each township corner, applying the small proportional correction for placing intermediate corners.

tude of the south boundary being 35° North, and length 42 miles, the latitude of the north boundary will then be 35° 20′ 52″, as the east and west boundaries are 24 miles long, and the side of a township = 5′ 13″ difference of latitude.

Log cos lat 35° 20′ 52″	9.9115092
Log 3360 chains	3.5263393
Co log cos 35°	0.0866355
Log 3345.68	3.5244840

3360—3345.68=14.32 chains convergency.

Since there are 4 rows and 7 tiers of townships in a check, by dividing 14.32 by 28 =51 links, the amount of convergency of a single township is found.

The 1st township nearest the Standard and Guide will close 51 links short. No. 2 will be 1.02 short. No. 3, 153 short. No. 4, closing to the northern boundary, 2.04 chains short.

The 2d tier closes 4.08 chains less than 12 miles from the east boundary; the 3d tier, 6.12; 4th, 8.16; 5th, 10.20; 6th, 12.24, and the guide, 7th, 14.32 chains short of the lengths of the southern standard included by the tiers.

All the above closings, except the last, are approximations sufficiently close for all practical purposes. The table of convergencies is constructed upon this principle, and may be used to construct maps as well as to prove field work.

The convergency in the above case being 14.32 chains, the bearing for running a line parallel to the eastern boundary of the check would be North 35′ West. Half of the angle so found is the amount required to be thrown toward the north in running the south boundary upon a true chord of latitude, by back sights from the starting-corner, making the course North 89° 42′ 30″ West apparently.

THE VERNIER COMPASS.

Two instruments are treated of, only, in this part, for the reasons following:

The Solar Compass is the best instrument so far invented, adapted to the multiform requirements of the United States surveys.

The Vernier Compass is next best, and combines lightness with simplicity of construction.

The Theodolite has been supplanted in use by the Transit and plain compass, because the great amount of workmanship and

its consequent cost of making, was not justified by the general inaccuracies of the magnetic needle, upon which, in government surveys, the instrument depended largely for its correctness, and in that kind of work the vertical circle was seldom used.

The Transit is better for railroad work, and could also be used in United States surveys, but its weight, and the care requisite to keep it in good order, and its greater liability to accidents, with the additional uselessness of a telescope for this kind of field work, renders it rather undesirable, particularly where rapid and accurate work is to be done.

Some surveyors, however, prefer the Transit, and the telescope has a few advantages in dense brushwood or timber over plain sights, but for general purposes the open-sight Vernier Compass is probably better. In mountainous country the transit is very useful.

The parts of the Vernier Compass consist of the circle, graduated to half degrees; the needle resting upon a pivot in the center of the circle, from which, by means of the needle lifter, a screw under the compass, the needle is raised when not in use, to prevent the pivot point from becoming blunt; the adjustable levels placed at right angles to each other; the ball and socket, for attaching the compass to a tripod or staff; the spring catch and screw, for fastening the spindle of the ball and socket firmly to the instrument; the sights, with slits and circular apertures through which the flag is ascertained to be "on line"; the sight screws at each end, and underneath the instrument; the tangent eye-pieces on the south sight, through which, by means of a card placed against the graduations upon the north sight, angles of elevation or depression may approximately be obtained; the upper eye-piece, for objects below the level of the station, and the lower eye-piece, for objects above; the vernier, for setting off smaller parts of bearings than can be read from the circle; the tangent screw, attached to the vernier, to impart, when desired, a slow motion to the vernier, in the direction of the circumference of the circle; and the clamp screw, binding the vernier in place.

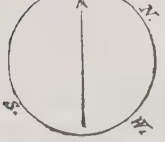


Fig. 30.

The circle plate is covered with glass, and has inscribed thereon the letters *N. S. E. W.*, to represent the cardinal points those letters indicate. The *W* is on the east side, and the *E* on the west side, because the compass, being placed with its south end next the surveyor,

the readings are taken from the north end of the needle; this arrangement enables the bearings to be taken direct from the compass without reference to any other aid.

For instance, in setting off the angle north 50° east, the instrument having its south end toward the surveyor, the needle points as in Fig. 30.

If the bearing is south 10° west, the needle at its north end will point to the proper graduation between the letters *S* and *W*, the observer always facing the object and keeping the letter *S* next his person.

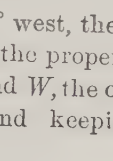


FIG. 31.

To use the compass, connect the ball and socket with the tripod, place the compass on the spindle, and level the instrument, let down the needle, align the sights, and having previously set off the variation of the needle upon the vernier, when the needle points to zero the bearing is north.

If the variation of the needle is west, the zero point of the vernier must be moved east, or toward the right; if east, the vernier is to be moved west, or toward the left hand.

To set off a variation of 15° 33′ east on the vernier it is unclamped, and by the tangent screw moved toward the left until the 0 point in the vernier is near 15° 30′ on the opposite arc, then move the vernier slowly until the third graduation from the 0 corresponds with a line of the arc.

The needle may then be pointed to the zero of the circle, and the sights will be directly north and south; no further attention need be paid to variation in using the compass at any angle, if its amount has been properly set off on the vernier.

Gurley, of Troy, New York, makes three sizes of this compass, having needles four, five, and six inches in length. The vernier for the six-inch needle compass is outside the needle-box, the smaller sizes having the verniers enclosed with the needle. The six-inch needle is the best size for all purposes, its weight being 9½ lbs., and cost $58.00, including tripod, box, etc.

To counteract the tendency of needles *dipping* or inclining their north ends toward the earth, the south end of each needle is weighted with a movable spiral ring of wire.

When the instrument is leveled, the sights should be perpendicular, the needle should always divide the circle into two parts, "cutting" opposite degrees. Friction against the glass cover

and other causes sometimes produces electricity, rendering the needle erratic, and it even may adhere to the glass, or refuse to traverse. This may be remedied by moistening the hand and passing it over the glass, or by pouring a little water over it.

When the needle is not in use it should be raised and allowed to preserve the direction of the magnetic meridian.

Instrument makers will lacquer or bronze the brass parts of compasses, if requested to do so, and as bronzing prevents the glare of the sun from injuring the eyes, as reflected from polished brass, this is a matter worth attending to in procuring instruments.

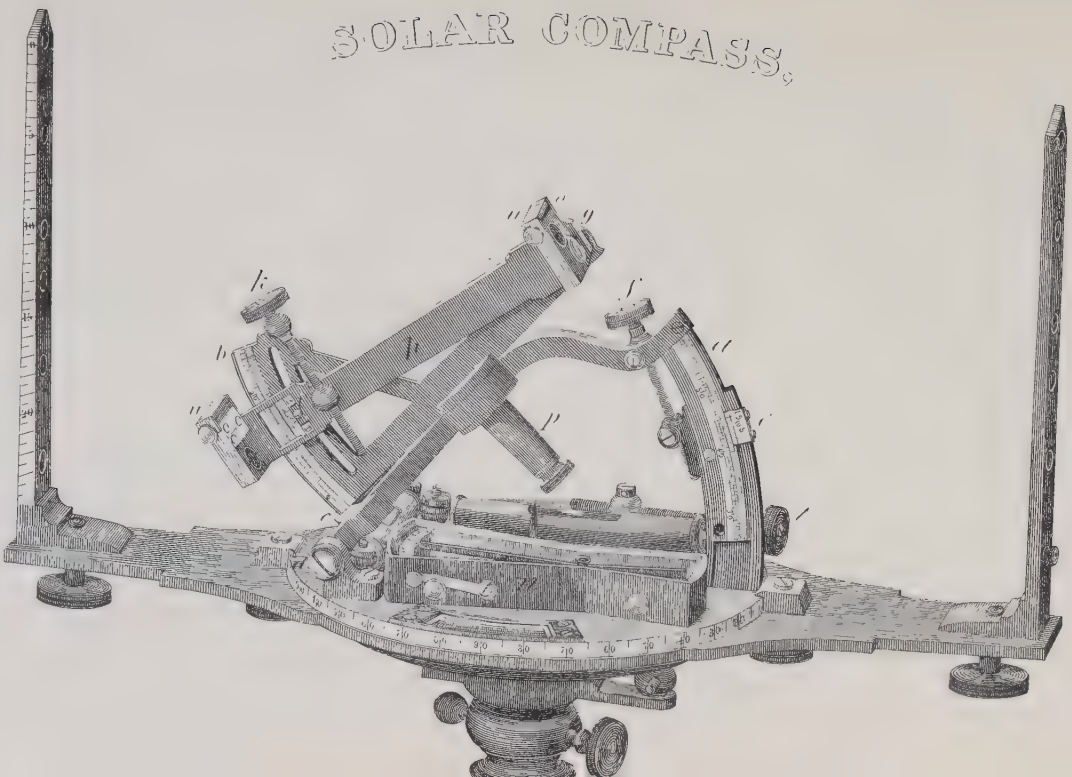
THE SOLAR COMPASS.

This instrument was invented by William A. Burt, of Michigan, and it has become the standard compass in U. S. Surveys. As it does not depend upon the magnetic needle in any way, lines run with it are true sun courses, and when used by a skilled surveyor are very accurate.

The government requires its standard and township lines to be run by its means, and in every class of work it will be found serviceable.

Its parts consist of latitude arc *a*, upon which is set off or ascertained the latitude of a station; the declination arc *b*, whereon the distance of the sun from the equator is set off; the hour arc *c*, which gives the hour angle of the sun, or the hours and minutes of the day; the horizontal arc or plates *d*, upon which may be turned off any desired angle; the needle arcs, one enclosed in the needle-box *n*, and the other resting upon the horizontal plate outside, by means of which the amount of departure of the magnetic needle from the true north may be determined; the needle-lifter, on the side of the box; the adjustable levels; the sights, as on the vernier compass; the polar axis *p*, or spindle of the declination arc; the declination arm *h*, attached to which are the solar lenses and blocks *g*, through and upon which the sun's image is produced, and guided between the equatorial and hour lines engraved on the block; the equatorial sights *u*, attachable to the blocks, and used in adjusting the instrument; clamp and tangent screws, *f*, *k*, *t*, and verniers *e*, *v*, and others attached to the principal arcs.

SOLAR COMPASS.



The image block attached to the declination arm receives the image of the sun (while lines are being surveyed) anywhere between the two principal horizontal equatorial lines; the perpendicular or hour lines being used in taking time or latitude when the image is kept between both sets of lines in the square formed at their intersection.

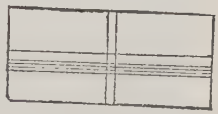


Fig. 32.

Below the equatorial are the refraction lines, 5′ apart, used when the sun is near the horizon, by causing its image to rest upon one or the other, as occasion requires.

A small dot in the center of the square facilitates an observation in determining the exact position of the image; the sun being nearer the earth in winter, causing its image to overrun or fill the lines, and in summer leaving a space between the limbs and lines, the dot assists in centering the image, particularly when the irradiated edges and lines do not coincide.

When the instrument is in adjustment, and the proper latitude and corrected declination set off upon the respective arcs, the latitude arc turned toward the south, and the sun's image resting between the equatorial lines, the motion of the arm *h*, when revolved on its spindle, will exactly correspond to and follow the sun's apparent motion through space, referred to the given day and place, and if the compass was stationary, proper allowance being made for change of declination and refraction, the image should remain between the equatorial lines from sunrise to sunset.

When the sun is east or west, the arm *h* is nearly at right angles, with its position as shown in the cut, the lens being turned toward the sun, and the block receiving the image opposite.

As the sun ascends the arm is moved, until at noon it becomes parallel with the latitude arc, the sun being in the meridian. At sunset the position of the arm is reversed from that occupied in the morning.

The arm is represented as being adjusted for south declination. When the sun is north of the equator the parts are inverted by being turned on the polar axis *p*, until *k b u* are in the places of *u o g*. The one arc answers for both plus and minus declinations, when the sun is north, the arc being turned upward and southward, and when the sun is south it is turned downward and

northward, there being two sets of blocks and lenses, one at each end, admitting their being used alternately for the different declinations.

A good solar, properly adjusted and leveled, with correct angles set off upon its various arcs, will not admit the sun's image between the equatorial lines until the sights are turned in the direction of the course desired. The least motion of the instrument to the right or left of the true course being indicated by the image passing above or below the lines.

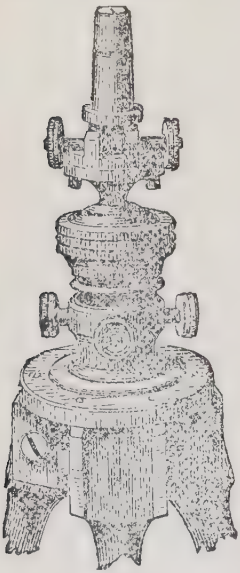


Fig. 33.

Gurley's adjusting socket and compound ball, with tangent movement, is an almost indispensable adjunct. The leveling plates and screws may be and are sometime ssubstituted for the apparatus nearest the tripod head, but, without the tangent-rack and screw to the spindle, very much of the utility of the solar compass is destroyed, unless some equivalent could be substituted.

The instrument is attached to the spindle, and, by means of the tangent, slowly and nicely revolved to its exact position without the jerking motion common to the simple ball and socket.

When approximately leveled by means of the ball, and accurately adjusted horizontally with the lower set of screws, it is then moved into line with the tangent-screw without deranging any other adjustment.

To determine latitude with the solar compass. Before lines can be run, it is necessary to ascertain the latitude of the starting-point with the instrument used. It will not answer to take the latitude as determined by other means, even though it be correct, for, while the solar is a great achievement in the way of surveying apparatus, it is a human affair and consequently fallible, and instruments are sometimes found with errors of from 3′ to 30′. Usually such errors are attributable to a slight displacement of a vernier, but often the error is not a constant quantity, and has to be guarded against carefully. Instrument makers will undertake to obliterate such errors, and often succeed.

Latitude is found by taking the declination of the sun for noon, calculated for the given day and place, and clamping the declination arm to that angle, approximately set off the latitude on the latitude arc, level the instrument carefully, and if during south declination, place the arc *b c*, with the *graduated side* next to and upon the center of the hour circle, at the 12 mark; if the declination is north, the other end of the arm is brought next the 12 mark, the *graduated side* being at the upper end, but in line with the graduation. Erroneous latitudes having resulted from using the wrong side of the arm, the italics were considered necessary. It will be seen that the center of the polar axis passes through and is even with the graduated side of the arm; for this reason it should be next the hour angle mark to be read.

Next revolve the instrument upon its spindle by means of the tangent screw, commencing about half an hour before apparent noon, and bring the image between both sets of lines into the square by raising or lowering the latitude with the tangent screw. Continue to keep the image between the equatorial lines with the tangent of the latitude arc, and between the hour lines with the tangent movement of the compound ball beneath the plates.

As the sun ascends, the image will fall below the lines, but must be kept in the square with the latitude arc tangent. There will occur a few minutes about noon, during which the sun and its image appears stationary in regard to ascent, during which the latitude will remain unchanged. This will be found to be the true latitude as given by the compass with which lines are to be run with that instrument. The image will soon be noticed passing above the lines, but this is only taken as an evidence that the sun has passed the meridian and is declining.

This is the only use made of the solar at the noon hour. From 11.30 to 12.30 lines cannot be run, nor can time be taken, the sun being on the arch.

An observation for time may be made before or after noon by reading the amount on the hour arc as indicated by the graduated side of the arm, and applying the equation of time according to its sign.

A method of verifying latitude observations is to take the latitude already ascertained, and at a certain hour before noon observe the bearing of an object; at an equal hour after noon, with the same latitude, but properly changed declination, notice if

the same object can be seen with the same bearing; if not, cause a flag to be placed to the right or left of the object observed before noon, in the spot observed with the original bearing in the afternoon, measure the distance from the first object to the flag, both of which should be in a line at right angles to a line from the compass to midway between the flag and object; then, by placing a flag half way between the first observed object and second, turning the sights with the same bearing upon this third flag or object, and raising or lowering the latitude arc until the image is between the equatorial lines, the error will be neutralized. This method requires more care than the first.

When the latitude and declination are correctly determined, and the instrument adjusted to those quantities, and being leveled and otherwise in perfect adjustment, the polar axis will only be parallel with the axis of the earth when the image falls between the equatorial lines; if this is done and the sights clamped at zero and 180°, the line projected both ways between the hair slits of the sights is a true meridian. By lowering the needle to its pivot and manipulating the tangent screw of the outer needle arc, the angle between the magnetic and true meridians may be ascertained direct.

To turn off any desired angle. Unclamp the binding screws at both ends of the plates, and also see that the tangent clamp is loosened. When the angle is nearly as desired clamp the last mentioned, and turn the tangent screw until the exact reading is obtained, then reclamp the binding screws. During this operation the solar part is stationary, and the lower plate carrying the sights should move without friction.

Running lines with the solar. The surveyor should, before commencing, refer to the nautical almanac for the sun's declination for the given day at Greenwich apparent noon, and if the longitude of the place is 5 hours west from Greenwich, the declination as given by the Ephemeris would correspond to 7 A.M. of the same day at the place 75° west from Greenwich.

It is customary to correct declinations for places by half hours of longitude; thus, 75° west longitude = 5 hours from Greenwich; 82° 30′ = 5 h. 30 m.; 90° = 6 h.; 97° 30′ = 6 h. 30 m.; 105° = 7 h.; 112° 30′ = 7 h. 30 m. Distances in longitudes nearest to those mentioned are changed in time to the hours and half hours next those longitudes.

Suppose, May 21st, 1870, we wished to prepare a field card of declination changes in longitude 79° 20′ west.

The nearest half hour of time to 97° 20′ is 6 h. 30 m., consequently on that meridian Greenwich noon is about 5 h. 30 m. A.M.

Greenwich declination, apparent noon, May 21st, 1870, was,

20° 12′ 3″.5=5 h. 30 m. A.M.

30 .4 change for 1 hour increasing.

20° 12′ 33 .9=6 h. 30 m. A.M.

The quantity 30″.4 is added to the declination for each hour to obtain the next hour.

Calling the latitude of the station 35° North, the meridional refraction would be found thus:

Lat. 35°= Co-lat. 55° + N. decl., 20°= 75°

approximate meridional altitude of sun.

The refraction corresponding to 75° altitude=15″.5.

May 21st, 1870,

Declination 6 h. 30 m. West of Greenwich=20° 12′ 3″.5

Meridional refraction + 15. 5

20° 12′ 19″ 5.30 A.M.

Hourly change 30″.4

20° 12′ 49″.4	6.30 A.M.
30″.4	
20° 13′ 19″.8	7.30 A.M.
30″.4	
20° 13′ 50″.2	8.30 A.M.
30″.4	
20° 14′ 20″.6	9.30 A.M.
30″.4	
20° 14′ 51″	10.30 A.M.
30″.4	
20° 15′ 21″.4	11.30 A.M.
30″.4	
20° 15′ 51″.8	12.30 P.M.

continued in this manner through the day.

If the sun's declination is *decreasing*, the hourly difference is subtractive, and when the declination is south the refraction is subtractive.

With the ascertained latitude and declination properly turned off, say, the surveyor has reached by 6.30 A.M. the corner 3 miles

north of his starting-point in latitude 35° North. The latitude of this place will be 35° 2′ 36″, which should be duly set off upon the latitude arc, and the declination arc made to read 20° 13′, which is as near to the declination as the vernier can be made to indicate.

By the time latitude 35° 5′ 13″, the township corner 6 miles north of latitude 35°, has been reached, the hour may be 7.30 A.M., the declination arc is changed, if necessary, in this instance not required, and the latitude arc increased 5′ from the reading used in the outset.

As a general rule change declination and latitude every hour and mile of line run, but there are occasions when the declination changes so slowly that nearly a day may elapse before any change is needed. On east and west lines, of course, the latitude does not change at all.

Remember to use the latitude as given by the particular instrument the lines are being run with, since index errors are frequent.

In running lines at any angle between the principal points of the compass, the latitude must be estimated by a traverse or trigonometrical operation, taking 52″ to the north or south mile of line.

The reflection from the declination arm sometimes creates a *false image*, which is thrown upon the image-block. Care should be taken that it is not mistaken for the true image—the latter being much brighter and better defined. In cloudy weather the covering of the solar lens can be moved to one side, allowing the image to be formed, unless the sun is totally obscured, when the only resource is the needle or back-sights.

An extra hole will be found in the latitude arc for the insertion of the clamp-screw, when used in high latitudes.

A fruitful source of errors is the liability of the horizontal plates "working off" from the proper course. This should not only be watched but all angles verified at every station. This can be done rapidly and without loss of time if the deputy becomes habituated to doing so.

The needle should be lowered at every station, and, if it does not point to zero, it should be made to do so by its tangent. The variation is noted by entering its amount in the tablets at every mile, and oftener, if any material change has taken place. Whe-

a sight is to be taken the tripod is spread over the sight-mound or station, the instrument carefully leveled, and in running north the sights clamped at zero, the latitude arc turned toward the equator, and with the needle brought approximately in line, then with the tangent-screw of the compound ball move the solar in the direction of its circumference, the time of day being roughly estimated and pointed to on the hour-arc by the arm, move the arm gently from side to side as the instrument is turned, and when the image is seen bring it between the equatorial lines. The flagman or sight-builder may then be placed.

The sun's image is kept below the equatorial lines when the sun is near the horizon, but at all other times between them. The inclination of the lines to the horizon tends to diminish much of the effects of refraction in using the solar, but, until some appliance is constructed to accurately dispose of refraction, the line should not be started upon until half an hour after sunrise, nor continued later than that time before its setting, unless accurate back sighting can be resorted to.

The rapidity of changes in refraction near the horizon precludes anything like exact allowance for it in using the solar, but, if necessary, an estimate may be mentally made of the amount to allow, and the image placed on the 5′, 10′, or 15′ refraction line below the equatorial, or even lower. Practice alone will enable the surveyor to successfully accomplish this.

The outer edge of the horizontal plate is graduated to enable approximate courses, to be taken by means of a pencil laid in line with the object upon the compass. The sights are also angentially graduated for estimating elevations, as described in the article on Vernier Compasses.

Telescopes with micrometer attachments, for dispensing with chaining, are sometimes placed in wyes over the sights. See Gurley's "Instrument Manual," which book accompanies all solars made by that firm, and contains instructions for adjusting the instrument.

PART III.

FLAGGING.

In prairie, hilly, or mountainous country, away from timber, the "sight mound" for rapid surveying is in many respects preferable to the flag, but either may be used.

The sight-man or flagman leads the entire party, the compassman, chainmen, mound or corner builders' wagons, with stakes, implements, etc., following in the order stated.

In flat prairie country, sights may be taken as far as the flagman can be seen, but where the country is in the least rolling or broken, he should be careful not to get out of view of the compassman, in endeavoring to reach some apparently or really higher point, which is obscured from the rest of the party by intervening objects.

Surveyors vary sometimes in the motions they use in flagging, but for uniformity's sake it is best to confine the signals to right, left, correct, or "down," return, and go ahead. The right and left motions are made on the respective sides of the compass, by waving hat, hand, or handkerchief, slowing the motions as the flagman is nearer the line. When on line, standing erect with spade or flag in front, the motion "down" is made by the surveyor extending both arms above his head, bringing them down to his sides. At long distances this motion may be accompanied by stooping at its close to render the signal more apparent.

The return signal is made by waving downward and backward, to go ahead, upward and forward.

When triangulating, the flagman should be previously instructed to remain in the same place while the bearings are being taken, if he is being sighted to, and not to move until he sees the go-ahead signal.

An intelligent flagman can achieve wonders in keeping on line, and in the author's experience a resident of Brecken-

ridge, Minnesota, resorted to methods worth mentioning in keeping aligned while acting as flagman. He rarely varied a foot from the true course, even when back sights were not visible. His plan was to back against the sight mound facing the compassman, move a few paces in that direction, about face, and stooping, bring the handle of the spade and the sight mound in line with some object ahead, then going to that spot, commence digging the sods for the next sight mound, having them ready to place by the time the surveyor had reached the station.

In this way a vast amount of time can be saved, and more work accomplished, and the vexations of having a wandering flagman be unexperienced.

If the flagman would, by an occasional glance toward the party, keep the rear chainman covered by the forward chainman, he can save himself many steps, and the whole party much annoyance.

When sighted, the spade should be brought down exactly between the feet in the place marked for the location of the sight mound. Inattention to this may occasion a bend in the line, requiring correction by retracing.

The mound is made by cutting five or six pieces of sod, placing them in a conical or pyramidal form over the station. If flags are used, the staves should be left in an upright position, otherwise the line will not be true.

CHAINING.

Gunter's Chain is 66 feet long, composed of 100 links, each 7.92 inches. There being 5,280 feet in a mile, 80 chains is equal to the same distance.

The facility with which areas of any size may be measured and computed by its means, is a peculiar feature of the 66 feet chain. By taking the side of a rectangle as many times in chains as there are chains measurement on the adjacent side, and cutting off the right hand figure with a decimal point, the area is obtained in acres.

For example: 80×80 chains$=640$ acres; 40×40 chains$=160$ acres; 3.50×7.85 chains$=2.7475$ acres.

The chain has brass tags or marks at intervals of 10 links from end to end, numbered from the handles toward the middle,

with notches in each tag indicating the number of tenths of the chain.

The proper place for the chainmen generally is behind the compassman and before the corner builders. The chain should always be held level when in use, even if found necessary to halve or quarter it in ascending or descending hills, the lower chainman holding up his end until horizontally straight.

There are eleven iron, steel, or brass pins, about a foot in length, with rings in the top, and sufficiently weighted at the points to cause them to drop perpendicularly. A strip of red flannel, six inches long, tied to the ring of each pin, makes them more conspicuous and easier to find in grass, etc.

In starting, the fore chainman takes the end of the chain in his right hand with one pin in that hand, with the other 9 pins in his left.

The hind chainman takes the other end of the chain in his right hand, holding it over the eleventh pin, which is always stuck while at work.

When the chain tightens as the chain is stretched, the hind man carefully brings the outer edge of his chain handle close to the top of the pin, and cries, "Stick!"

The fore man sticks the pin from his right hand plumb in the earth, observing that the outer handle touches the pin, and that the chain is stretched, and cries, "Stuck!"

Hind man then pulls the pin with his right hand, passing it to his left, into which he gathers the other pins, as the work progresses.

Fore man then leaves the pin he stuck, and looking at flag or sight mound, proceeds straight toward it until the chain tightens, and hind man cries, "Stick!" again.

In this way, the ten chains are run out, whereupon the leader cries, "Tally one!" loud enough for the compassman to hear, waiting at the last pin which is left sticking, while the hind man drops his end of the chain, comes forward and counts the pins in presence of the other, and, taking the forward end of the chain, leads the way on the second tally—the last chainman becoming the first. In this way, one is ahead in all the even and the other in all the odd tallies.

The chainmen should cry the number of tallies from one to eight; the fourth tally, or forty chains, being the place for the

quarter-section corner, at which spot the chainmen wait until the corner builders arrive, the eighth tally being the place for the section corner.

In running principal and standard lines, two sets of chainmen pass over the same line. The instructions require that they should be kept apart and not allowed to communicate with each other. Probably the best way to accomplish this is for the surveyor to keep between the two chaining parties. The mean of the two measurements are taken for corners, unless grossly different, any such difference requiring a re-measurement from the last corner. A garrulous or over-lively chainman should have for a companion one of more quiet demeanor, and, until the station ahead is established, they should not proceed except with back sights. They should be required to keep the line without rushing from side to side on guessed at or neglected sights, as some are prone to do unless checked.

A light steel chain with adjustable handles, costing about $14, is the best for all kinds of work. Care should be taken to keep the chain from kinking, lengthening or shortening, by comparing it regularly with a standard measure.

The chainman should keep account of and report the distance from corners to roads or streams crossed, and other noteworthy objects passed on line.

BLAZING.

True lines are blazed or cut by the axemen of the party cutting the trees two inches or over in diameter, on both sides of the tree, with a chop or notch "quartering" toward the line, so as to be readily seen and followed. Trees on line are cut on both sides parallel to the line.

The chops or notches are made diagonal with the line in cases where the trees are near, but if the trees are distant from the line the notches are made nearer parallel, and facing the line the farther away they may be.

No blazing is done on random lines, but stakes or other temporary marks should be set every ten chains or oftener, if needed, and removed when the true line is blazed.

CORNER BUILDING.

Paragraph 3, page 3, Instructions, requires stone to be used for corners in all cases where practicable, the minimum size being $14 \times 12 \times 3$ inches $= 504$ cubic inches, or any other dimensions containing a similar number of cubic inches. The stone should be inserted in the ground 7 or 8 inches, with edges in the direction of the line, the dimensions and kind of stone to be stated in the field notes. All corner stones 14 inches long or more, and less than 18 inches, are to be set two-thirds of their length in the ground; if over 18 inches, three-quarters of their length.

Stones or posts for section corners inside a township are notched on the south and east edges with as many notches as they are miles from the south and east boundaries of the township. On township or lines other than subdivisional, the marks are placed on the edges in the direction of the line, with as many notches as they are miles from the township corners. Thus, the second mile east of a township corner would have 2 notches on the eastern and 4 on the western sides; if one mile from the south boundary, 1 notch south and 5 north, etc. Township corner stones have 6 notches on each of the four sides.

All quarter-section corner stones are marked with "$\frac{1}{4}$."

Stone hammers and chisels are needed in marking stones.

The dimensions are placed in the field notes in the order of the largest first, $14 \times 12 \times 3$ inches.

Stones in corners on a base or standard line common to two townships only, are marked on the north, east, and west sides for corners common to the two townships north; and south, east and west sides, for corners common to two townships south.

Trees found to be at the corners to sections are marked as posts, first chopping off the bark on the four sides, unless it is a beech or other smooth-bark tree, when the marks are cut in the bark and the tree notched.

Where stones abound, corners are marked by a small pile of stones, alongside a single marked stone. In all cases where stones are used it is best to have a mound of earth or stone placed on the side of the corner stone, on line with the regular pits, whether required to do so or not, as by so doing the corners are easier found after being established.

When no tree is at the corner and stones suitable are not to be

found, a mound of earth or stones is to be raised around posts on which the corners are marked as instructed below.

These mounds are conical, according to instructions, but in the greater number of districts it is found not only absolutely necessary to build them in the shape of a quadrangular pyramid, but, from the nature of the soil, almost impossible to make them any other shape.

Before building the mound, the "memorial" is deposited, in the shape of any quantity of charcoal, a glass bottle, or marked stone (account of which is duly taken) at the corner, in a small hole dug for the purpose about one foot deep, which hole also receives the lower end of the post.

A charred stake about one foot in length may be substituted for the charcoal or other memorial, and either is to be placed on that side of the post in the direction of the running of the line; on the east if the line is run east, etc.

Township mounds are five feet in diameter at their bases, and two and a half feet high; the posts are five inches wide and four and a half feet long, one foot of which is in the earth, and one foot exposed above the mound. All other mounds are four and a half feet at base and two feet high, the posts being four inches wide and four feet long, placed as in township mounds.

Four pits are made six feet from the mound at township and section corners, and in some districts at quarter-section corners, but the reasons for digging two pits only on line at quarter corners are so obvious that it is to be hoped all surveyors—general and chief clerks, will so construe instructions, which are rather ambiguous on this subject, into allowing the two pits only in such cases.

The pits for a township corner are eighteen inches by two feet wide and at least one foot deep, at section corners eighteen inches square and one foot deep

"At township corners common to four townships, the pits are placed on line. On base and Standard lines, where corners are common to two townships or sections, three pits are placed, one on each side on line, and the third on the line, north or south of the corner, as the line runs north from or closes from the south to the standard or base."

Section corner pits are placed N. E., N. W., S. E., and S. W.,

of the corners, one in each section. Township corner posts are marked with the number of the townships and ranges, as T. 13 N., R. 7 W.; T. 14 N., R. 8 W., for a corner common to townships 13 and 14 north of the base, and ranges 7 and 8 west of the principal meridian.

Section corners are marked with the sections, range, and township to which they belong, as T. 13 N. 26 (on the N. W. side), R. 7 W. 25 (on the N. E. side), S. 36 (southeast), S. 35, (southwest), the numbers being cut upon the sides of the sections they face.

Section corners on meridian township lines have both ranges, the township, and sections marked on them, and on east and west township lines, both townships, the range, and sections cut upon the posts.

All posts face the sections they belong to, and are set diagonally with the line.

Quarter-section corner posts are marked simply $\frac{1}{4}$ S. on a "flattened surface" squaring three inches.

Section corner posts are four inches wide, squaring three inches. Township posts are required to be five inches wide, squaring four inches, and all posts are bevelled at the top "to shed rain."

There is one requirement that should take its place with the quadrangular trench and seed-planting abolished by the supplementary instructions; it is that of applying a "streak of red chalk" to the figures on posts. Something almost wholly disregarded by surveyors, although in the instructions. It is so evident to the deputy or any one else, that the streak of chalk would remain only till the next rain, that they prefer exceeding instructions in other respects than complying with so useless a demand. The notches should not be omitted if the chalking is, and even that had better be done until abolished by law.

Standard section and standard township corners have three pits, dug north, east, and west on line, and the post is most conveniently made prismoidal. Upon the south face the letters S. C. for standard corner, should be marked, instead of the number of the township it faces on that side. Corners closing on the stand- and are marked C. C. for closing corner, on the north face of the prismoidal posts, the pits being three in number, east, west, and south.

The manual gives four sides to the standard post, but in the paragraph mentioning it, on page 15, the spirit of the law can be interpreted into making a three-sided post, as the intention is to clearly distinguish between standard and all other lines.

If from any cause the north boundary of a check is not completed before the closing lines from the south have been run, the deputy working from the south will establish at full 80 chains a temporary corner, which it becomes the duty of the surveyor running the standard, to move upon his line, reporting the closings and distances to the office.

Page 10, paragraph 2, establishing corner boundaries, says: "In a region where timber is not near and stone not found, the corner will be a mound of earth of prescribed size, varying to suit the case."

Spades used in building mounds should be sharpened by a long bevel filed upon the face, and a short bevel on the back. By placing the spade handle between the wagon box and wheel spokes, an impromptu vice is made, holding the spade firmly while undergoing sharpening.

WITNESS CORNERS.

When, from any cause, such as encountering a lake, ravine, slough, etc., a corner cannot be built in its appropriate spot, a witness corner is constructed, in every respect resembling the kind of corner that would have been built at the regular location, in the most convenient place nearest the proper place, on the line that is being run; and in addition to the ordinary marks the letters W. C. should be cut on the post, and the distance from the true place not only noted in the tablets, but legibly pencil-marked on the post for the benefit of subsequent surveyors, particularly in cases where exterior and interior lines are being run the same season, and the witness corner is on an exterior line in the place of a closing corner.

MEANDER CORNERS.

Wherever a meanderable body of water is encountered on any line, a corner of some kind is built of stones or earth, or a tree may be marked for such corner. When a mound is built it must have the dimensions of a quarter-section corner, the post of

similar size, and either tree or post marked M. C.; in addition to which, if the body of the water is a navigable stream or lake, the numbers of the fractional sections, ranges, and townships, should be also marked thereon.

Meander corners are built upon both sides of the obstacle in the place where the line intersects it. The pit in this case is to be built 8 links further from the water's edge than the mound, and from this statement in the manual it can be inferred that but one pit is required.

A meander corner takes the place of a witness corner on meanderable lakes, etc., in which case the M. C. has precedence; or a section and quarter-section corner may take the place of the meander corner, in which event it is designated as a section and meander, or quarter-section and meander corner.

Special meander corners are built upon islands not on line, as directed in meandering.

BEARING TREES OR OBJECTS.

When possible, corners of all descriptions should be perpetuated by the courses and distances being taken from corners to the nearest tree $2\frac{1}{2}$ inches or more in diameter, within 3 chains of such corners.

They are blazed largely and smoothly, with a notch at the lower end of the blaze facing the corner, and upon the blaze is marked the range, township, and section, except at quarter-section corners, when $\frac{1}{4}$S only need be marked. The letters B. T. are marked on a smaller blaze underneath the other, and near the ground.

At all township and section corners the number of bearing trees corresponds to the number of sections to which such corners are common, one tree in each section.

From quarter-section and meander corners two bearing trees are taken, one in each adjoining section. The witness corner being in place of another corner has the number of bearing trees usual to the corner it represents.

Where a large rock or other notable object falls within bearing tree distance it should be marked, if convenient to do so, and recorded.

BEARING OF LAND AND WATER OBJECTS.

In running lines, particularly standard and township, it is advisable, wherever any object of importance, such as a lake, forest, spring, hillock or "butte," old Indian battle-field, lone tree, etc., is seen wholly within and at any distance from the lines, to take from the point where visible the bearing of such object, and as the line progresses at some other point take another bearing, by which means its location may be determined without measurement, and, as in the case of dry country, these notes may become specially useful to the surveying parties on interior work, the deputy who makes the notes being liable to be benefitted himself at some future period by knowing the location of springs, ponds, etc., in the work he may survey.

In projecting irregular standards through a country too mountainous or barren to admit of subdividing, these notes have a peculiar value as references.

CLOSING LIMITS.

All north and south section lines, except those next the north boundary of a township, must be 80 chains in length.

The east and west section lines, except those in the tier adjoining the west boundary of a township, or in closing to state and reservation boundaries from any direction, are to be within one chain of the distance established on the south boundary of the township for the width of such tier of sections.

The north and south boundary of any one section, except in the extreme western tier, are to be within one chain of equal length.

The meanders within each fractional section, or between any two meander posts, or of a pond inside a section, or island, must close within 1 chain and 50 links.

Random township lines should not exceed or overrun in length, or close north or south of the township corner 3.50 chains.

These closings are given in the Supplemental Instructions.

TOPOGRAPHY.

The noteworthy objects on line consist of everything of interest or importance tending to fix the character and give the features of the country surveyed.

The quality of the soil, whether first, second, or third rate, and the surface of the country, whether level, rolling, broken, or mountainous, should also be recorded.

The field notes always contain a general description of the country, and should also give the distances from nearest corners to roads, streams, lakes, reservations, trees on line, groves or forests, bottom lands, hills, benches, table lands, mountains, ravines, springs, improvements, mines, quarries, rock ledges, fortifications, ancient mounds, etc., etc.

When any change in the soil or character of the country is found, the distance of meeting and leaving such place should be noted from the last section corner.

The width of all streams, lakes, sloughs, ravines, etc., the height of all remarkable hills, buttes, cascades, etc., the variation of the needle upon every mile must be set down, with the kinds of water found en route, saline, pure, or impure.

Any information, geological, meteorological, or chemical, in the ability of the deputy to note, in connection with the formation, rocks, weather, or salubrity of climate, and water supply, should be also given.

Swamp lands and their confines should be particularly recorded, as all such lands, unfit for cultivation, are donated to the States within whose boundaries they are situated.

OUTFITTING.

The style of "outfit" needed for a government survey, varies with the kind of land to be surveyed. In open prairie country, wagons drawn by mules or horses are best for transporting supplies, mules being found more serviceable than horses.

In mountainous country, pack animals, donkeys, mules, or ponies, are used, and in dense timber, swamps, or among cane brakes, it may be necessary to carry all supplies on the backs of men.

Since the kind and quantity of outfit needed differs materially with the climate, country, and number of men composing the party, a list of articles ordinarily carried, is appended, to enable the surveyor to make his selections, without finding, when in the field, that much has been forgotten.

Provisions, etc.—Flour, cheese, crackers, pork, bacon, lard, potatoes, coffee, tea, sugar, salt, pepper, vinegar, navy beans,

baking-powder, split peas, dried apples, blackberries, and peaches, canned corn, tomatoes, lima beans, rice, cornmeal, hominy, butter, syrup, matches, soap, toweling, wax or paraffine candles, horse-feed.

Implements, etc.—Compasses, chains, pins, marking-irons, hammers and stone chisels, flat and round files, whetstone, spades, axes, hand-axes, wrench, guns and ammunition, fishing tackle, small cooking camp stove, dish pans, tin pails, tin basins, quarts (in lieu of plates), butcher-knives, spoons, fry-pans, kettles, tin cups, with swinging handles, tacks for nailing boots, needles, awls, thread, twine, coffee-mills, baking-ovens with lids, wall and common tents, blankets, buffalo robes, ponchos, boots or shoes with scotched or broad soles, and other suitable apparel, including white woolen hats, with broad brims, silk neckerchiefs of some light color, not red, field-glasses, kegs for water, guy ropes for tents, books of instruction, tables, tablets, field notes, and writing implements.

The following is a cheap and simple process for rendering tents, wagon-covers, etc., water-proof, without stiffening them:

"Dissolve soft soap in hot water, add a solution of sulphate of iron (copperas). The sulphuric acid combines with the potash in the soap, and the oxide of iron is precipitated with the fatty acid, forming insoluble iron soap. Wash and dry this precipitate, mix with linseed oil, and with or without the addition of dissolved india rubber, a paint is obtained which renders all fabrics to which it is applied, impervious to moisture."

CONDENSING AND NEUTRALIZING ALKALI WATER.

Vast areas of the West are filled with streams, ponds, and lakes, bitterly alkaline, and in many instances surveying parties have no means of obtaining water for drinking and cooking purposes, except from such places, and it is no uncommon thing for men and animals to become sick, reduced and enfeebled by its use. Some method should be adopted to convert it into a less impure condition, and probably the most practicable way is by condensation or distillation.

Alkaline water, as found in such places, owes its bitterness to the presence of large quantities of potash, and is otherwise generally impure, from an admixture of carbonates, calcium salts, silica, sulphates, chlorides, and alumina, doubtless originating

from numberless prairie or forest fires. The vegetable salts of potassium being deposited in the shape of crude potassa and washed into the lakes or ponds draining the region. It is so soluble that water is capable of holding nearly its own weight of the substance in solution.

The enormous quantity of acid required to neutralize these waters precludes their treatment in this way, and the fact that the resulting liquid would possess in many cases medicinal properties, from aperients to poisons, it is neither desirable nor safe to attempt their neutralization in the primitive manner unavoidable in the field.

If the water is but little impregnated with potassa or other earths, salts or impurities, not sulphurous, the introduction of citric acid, in excess, changes the taste agreeably.

"The addition of two or three grains of alum to the quart cleanses muddy or turbid water, but often renders it harder than before. When alum is added the water should not be used under twenty-four hours.

"Freezing purifies water by expelling its saline contents, particularly carbonate and sulphate of lime."

Boiling kills most animal and vegetable organisms, expels gases, and precipitates carbonate of lime.

Filtering does not take up the dissolved alkaline materials, and charcoal used in filtering water impregnated with potassa would impart undesirable, if not poisonous, properties to the water.

Distillation is about the only resort, and the apparatus need not be expensive or bulky, but lead should never be used in its construction, as distilled water takes it up in injurious quantities.

The forms of stills may vary greatly, but consist essentially of three parts: the body or vessel containing the water to be distilled, which is placed on the fire, and may be made from an ordinary large camp kettle; the head or cover, closing tightly over the body, with a lateral tube of tin or copper projecting from the upper part joined to the worm; the worm, a long, spiral tin or copper tube, placed in a cistern or tub constantly filled with cold water.

The object of the worm is to condense the vapor by exposing a greater extent of cold surface.

The purified water is drawn off at the lower end of the worm.

The cold water is best introduced in the cistern by means of a

funnel as high as the top of the cistern, into which the water is poured, passing out of the tub or cistern through a hole near the top of the cistern, as the warmed water rises.

The first two or three pints of water distilled over should be rejected as liable to contain ammoniacal and other volatile impurities, and when four-fifths have been distilled, the operation should cease, and the body cleansed of sediment.

The condensed water, like melted ice and boiled water, will be insipid until exposed to the air some time. Its aeration can be assisted by pouring from one vessel into another repeatedly.

TABLETS.

A small blank-book is carried by the deputy, in which all entries of topography, peculiarities of the country, lengths of lines, closings, etc., should be made, and from which the more complete field notes are written.

The first page should be devoted to a diagram of a subdivided township, to which references may be made for the proper numbers to be marked on stakes and entered in the tablets; and in running township exteriors, a rectangular figure should be placed in the book, representing two sides of a township, giving the adjacent section numbers in two ranges, and two townships along the north and south and east and west lines separating them.

Checks may similarly be drawn in the tablets, showing the numbers of the sections, townships, and ranges, with the calculated closings.

Tablets can be abbreviated very much, but it is advisable to write them in such a way as will render them intelligible to another surveyor, as such notes can be made available in case of accidents disabling the deputy from continuing the work or explaining the tablets.

FIELD NOTES.

Blank books are furnished by the Surveyor-General, in which may be entered the notes of one subdivided township, two tiers of township lines, or a Standard Parallel and Guide Meridian.

No marks are to be made on the covers by the deputies. The title of the book and other details are entered on the first page as follows:

"Field Notes of the Subdivision Lines and Meanders of Township 13 North of Principal Base, Range 8 West of the 1st Principal Meridian. Surveyed by John Smith, United States Deputy-Surveyor, under contract dated January 1st, 1874. Survey commenced March 10th, 1874, completed March 20th, 1874."

The second page contains the statement in regard to measuring the west boundary of Section 36. The next concerns the measurement of the south boundary.

The first line of each page is devoted to the heading giving the township, range and principal meridian numbers.

The specimen field notes in the old "Instruction Manual" may now be used, devoting one page to each mile, and leaving a blank line between the description of the random and true lines.

Next follows the general description, list of names, deputy's affidavit, and room is left in the remaining pages for the Surveyor-General's certificate of examination.

The notes of other classes of surveys do not differ materially from the foregoing, in so far as the descriptions, etc., are concerned; the directions and lengths of lines varying, of course.

The township notes of random courses are only general; all topography being noted upon the return or true line. Some slight changes have been made from the "Manual" specimen, in practice, whereby the notes are rendered less voluminous in some respects, and more so in others. The statement, "Built corner according to 'Instructions,'" not being considered sufficient, each corner must be described in full; and instead of correcting lines with an altered variation, according to the old "Instructions," the variation remains unchanged on the corrected or true line, the course of such line being given with the unchanged variation.

TABLE OF CONVERGENCIES.

North Latitude	24 by 42 miles check.	30 by 48 miles check.	Tier of Townships 6 by 24.	Township 6 by 6.	Correction Angles.			Lengths of Parts of the Meridian and Degrees of Longitude.		
					12 miles E. & W.	48 miles E. & W.	6 miles E. & W.	Convergency angles, 42 miles check.	Meridian. 1 Mile	Meridian. 6 miles	Degree of Longitude Miles.
	Chains	Chains	Chains	Chains							
25°	9.56	13.62	1.36	.34	9′	10′	1′	17′ 15″	52″.31	5′ 13″.81	62.71
26	10.00	14.30	1.43	.36				17 40			62.20
27	10.43	14.90	1.49	.37		11		18 40			61.67
28	10.89	15.54	1.55	.39	10			19 30			61.11
29	11.35	16.21	1.62	.40		12		20 20			60 54
30	11.82	16.89	1.69	.42	11		2	21 10	.52 .27	5 13 .6	59.95
31	12.30	17.58	1.76	.44		13		22			59.34
32	12.79	18 28	1.83	.46				22 50			58.71
33	13.23	18.98	1 90	.48	12	14		23 40			58.06
34	13.80	19.71	1.97	.49				24 35			57 40
35	14.32	20.47	2.05	.51	13	15		25 35	.52 .23	5 13 .3	56.72
36	14.86		2.12	.53				26 35			56.02
37	15.41		2.20	.55	14			27 35			55.30
38	15.98		2.28	.57				28 35			54.57
39	16.55		2.36	.59	15			29 35			53.82
40	17.15		2 45	.61				30 35	.52 .18	5 13 .10	53 06
41	17.76		2.54	.63	16			31 45			52 27
42	18.40		2.63	.66				32 55			51.48
43	19.05		2.72	.68	17			34 10			50.66
44	19.72		2.82	.70	18			35 20			49.83
45	20 40		2.91	.73	18		3	36 30	.52 .14	5 12 .83	48.99
46	21.15		3.02	.75	19			37 55			48.13
47	21.90		3.13	.78	20			39 15			47.25
48	22.69		3.24	.81				40 40			46.36
49	23.49		3.36	.84	21			42 5			45.46
50	24.33		3.48	.87	22			43 30	.52 .09	5 12 .54	44.55

This table is calculated for the Latitudes from which the lines are projected For Latitudes of closing points add 5′ 12″ to each meridional 6 miles in first column, the other columns remaining unchanged.

MEAN REFRACTIONS.

TEMPERATURE 50°, PRESSURE 29.6 INCHES.

From Chambers's Astronomy.

ALTITUDE.	REFRACTION.	ALTITUDE.	REFRACTION.	ALTITUDE.	REFRACTION.	ALTITUDE.	REFRACTION.	ALTITUDE.	REFRACTION.	ALTITUDE.	REFRACTION.
0° 0′	33′ 0″	1° 30′	21′ 15″	4° 30′	10′ 48″	10° 30′	5′ 0″	25° 0′	2′ 2″	55° 0′	40″
5	32 10	49	20 18	45	10 20	11 0	4 47	27 0	1 51	57 0	37
10	31 22	50	19 25	5 0	9 54	12 0	4 23	29 0	1 42	59 0	34
15	30 36	2 0	18 35	15	9 30	13 0	4 3	31 0	1 35	61 0	32
20	29 59	10	17 48	30	9 8	14 0	3 45	33 0	1 28	63 0	29
25	29 6	20	17 4	45	8 47	15 0	3 30	35 0	1 21	65 0	26
30	28 23	30	16 24	5 0	8 29	16 0	3 17	37 0	1 16	68 0	23
35	27 41	40	15 45	30	7 51	17 0	3 4	39 0	1 10	71 0	19
40	27 0	50	15 9	7 0	7 20	18 0	2 54	41 0	1 5	74 0	16
45	26 20	3 0	14 36	30	6 53	19 0	2 44	43 0	1 1	77 0	13
50	25 42	15	13 39	8 0	6 29	20 0	2 35	45 0	57	80 0	10
55	25 5	30	13 6	30	6 8	21 0	2 27	47 0	53	83 0	7
1 0	24 29	45	12 27	9 0	5 48	22 0	2 20	49 0	49	86 0	4
10	23 20	4 0	11 51	30	5 31	23 0	2 14	51 0	46	89 0	1
20	22 15	15	11 18	10 0	5 15	24 0	2 8	53 0	43	90 0	0

APPROXIMATE EQUATION OF TIME.

From Chambers' Astronomy.

DATE.	MINUTES.		DATE.	MINUTES.		DATE.	MINUTES.		DATE.	MINUTES.	
Jan. 1	4	Clock faster than the Sun.	April 1	4	Clock faster.	Aug. 9	5	Clock faster.	Oct. 27	16	Clock slower than the Sun.
3	5		4	3		15	4		Nov. 15	15	
5	6		7	2		20	3		20	14	
7	7		11	1		24	2		24	13	
9	8		15	0		28	1		27	12	
12	9					31	0		30	11	
15	10		19	1	Clock slower.				Dec. 2	10	
18	11		24	2		Sept. 3	1	Clock slower.	5	9	
21	12		30	3		6	2		7	8	
25	13		May 13	4		9	3		9	7	
31	14		29	3		12	4		11	6	
Feb. 10	15		June 5	2		15	5		13	5	
21	14		10	1		18	6		16	4	
27	13		15	0		21	7		18	3	
Mch. 4	12					24	8		20	2	
8	11		20	1	Clock faster.	27	9		22	1	
12	10		25	2		30	10		24	0	
15	9		29	3		Oct. 3	11				
19	8		July 5	4		6	12		26	1	Clock faster.
22	7		11	5		10	13		28	2	
25	6		28	6		14	14		30	3	
28	5					19	15				

TABLE,

CONTAINING

THE LOGARITHMS OF NUMBERS

FROM 1 TO 10,000.

NUMBERS FROM 1 TO 100 AND THEIR LOGARITHMS,

WITH THEIR INDICES.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1	0·000000	21	1·322219	41	1·612784	61	1·785330	81	1·908485
2	0·301030	22	1·342423	42	1·623249	62	1·792392	82	1·913814
3	0·477121	23	1·361728	43	1·633468	63	1·799341	83	1·919078
4	0·602060	24	1·380211	44	1·643453	64	1·806180	84	1·924279
5	0·698970	25	1·397940	45	1·653213	65	1·812913	85	1·929419
6	0·778151	26	1·414973	46	1·662758	66	1·819544	86	1·934498
7	0·845098	27	1·431364	47	1·672098	67	1·826075	87	1·939519
8	0·903090	28	1·447158	48	1·681241	68	1·832509	88	1·944483
9	0·954243	29	1·462398	49	1·690196	69	1·838849	89	1·949390
10	1·000000	30	1·477121	50	1·698970	70	1·845098	90	1·954243
11	1·041393	31	1·491362	51	1·707570	71	1·851258	91	1·959041
12	1·079181	32	1·505150	52	1·716003	72	1·857332	92	1·963788
13	1·113943	33	1·518514	53	1·724276	73	1·863323	93	1·968483
14	1·146128	34	1·531479	54	1·732394	74	1·869232	94	1·973128
15	1·176091	35	1·544068	55	1·740363	75	1·875061	95	1·977724
16	1·204120	36	1·556303	56	1·748188	76	1·880814	96	1·982271
17	1·230449	37	1·568202	57	1·755875	77	1·886491	97	1·986772
18	1·255273	38	1·579784	58	1·763428	78	1·892095	98	1·991226
19	1·278754	39	1·591065	59	1·770852	79	1·897627	99	1·995635
20	1·301030	40	1·602060	60	1·778151	80	1·903090	100	2·000000

NOTE.—In the following part of the Table, the Indices are omitted, as they can be very easily supplied. Thus, the index of the logarithm of every integer number, consisting only of one number, is 0; of two figures, 1; of three figures, 2; of four figures, 3: being always a unit less than the number of figures contained in the integer number. The index to the logarithm of every number above 100, in the following part of the Table, is omitted; yet, in the operation, it must be prefixed, according to this remark: so that the logarithm of 600 is 2·77815, and that of 6000 is 3·77815, and so of the rest.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
100	000000	000434	000868	001301	001734	002166	002598	003029	003461	003891	432
1	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
2	8600	9026	9451	9876	010300	010724	011147	011570	011993	012415	424
3	012837	013259	013680	014100	4521	4940	5360	5779	6197	6616	420
4	7033	7451	7868	8284	8700	9116	9532	9947	020361	020775	416
5	021189	021603	022016	022428	022841	023252	023664	024075	4486	4896	412
6	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
7	9384	9789	030195	030600	031004	031408	031812	032216	032619	033021	404
8	033424	033826	4227	4628	5029	5430	5830	6230	6629	7028	400
9	7426	7825	8223	8620	9017	9414	9811	040207	040602	040998	397
110	041393	041787	042182	042576	042969	043362	043755	044148	044540	044932	393
1	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
2	9218	9606	9993	050380	050766	051153	051538	051924	052309	052694	386
3	053078	053463	053846	4230	4613	4996	5378	5760	6142	6524	383
4	6905	7286	7666	8046	8426	8805	9185	9563	9942	060320	379
5	060698	061075	061452	061829	062206	062582	062958	063333	063709	4083	376
6	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
7	8186	8557	8928	9298	9668	070038	070407	070776	071145	071514	370
8	071882	072250	072617	072985	073352	3718	4085	4451	4816	5182	366
9	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
120	079181	079543	079904	080266	080626	080987	081347	981707	082067	082426	360
1	082785	083144	083503	3861	4219	4576	4934	5291	5647	6004	357
2	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
3	9905	090258	090611	090963	091315	091667	092018	092370	092721	093071	352
4	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
5	6910	7257	7604	7951	8298	8644	8990	9335	9681	100026	346
6	100371	100715	101059	101403	101747	102091	102434	102777	103119	3462	343
7	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
8	7210	7549	7888	8227	8565	8903	9241	9579	9916	110253	338
9	110590	110926	111263	111599	111934	112270	112605	112940	113275	3609	335
130	113943	114277	114611	114944	115278	115611	115943	116276	116608	116940	333
1	7271	7603	7934	8265	8595	8926	9256	9586	9915	120245	330
2	120574	120903	121231	121560	121888	122216	122544	122871	123198	3525	328
3	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
4	7105	7429	7753	8076	8399	8722	9045	9368	9690	130012	323
5	130334	130655	130977	131298	131619	131939	132260	132580	132900	3219	321
6	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
7	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
8	9879	140194	140508	140822	141136	141450	141763	142076	142389	142702	314
9	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	146128	146438	146748	147058	147367	147676	147985	148294	148603	148911	309
1	9219	9527	9835	150142	150449	150756	151063	151370	151676	151982	307
2	152288	152594	152900	3205	3510	3815	4120	4424	4728	5032	305
3	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
4	8362	8664	8965	9266	9567	9868	160168	160469	160769	161068	301
5	161368	161667	161967	162266	162564	162863	3161	3460	3758	4055	299
6	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
7	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
8	170262	170555	170848	171141	171434	171726	172019	172311	172603	172895	293
9	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
150	176091	176381	176670	176959	177248	177536	177825	178113	178401	178689	289
1	8977	9264	9552	9839	180126	180413	180699	180986	181272	181558	287
2	181844	182129	182415	182700	2985	3270	3555	3839	4123	4407	285
3	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
4	7521	7803	8084	8366	8647	8928	9209	9490	9771	190051	281
5	190332	190612	190892	191171	191451	191730	192010	192289	192567	2846	279
6	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
7	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
8	8657	8932	9206	9481	9755	200029	200303	200577	200850	201124	274
9	201397	201670	201943	202216	202488	2761	3033	3305	3577	3848	272

No. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Diff.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	0·000000		10·000000		0·000000		Infinito.	60
1	6·463726	501717	000000	00	6·463726	501717	13·536274	59
2	764756	293485	000000	00	764756	293483	235244	58
3	940847	208231	000000	00	940847	208231	059153	57
4	7·065786	161517	000000	00	7·065786	161517	12·934214	56
5	162696	131968	000000	00	162696	131969	837304	55
6	241877	111575	9·999999	01	241878	111578	758122	54
7	308824	96653	999999	01	308825	96652	691175	53
8	366816	85254	999999	01	366817	85254	633182	52
9	417968	76263	999999	01	417970	76263	582030	51
10	463725	68988	999998	01	463727	68988	536273	50
11	7·505118	62881	9·999998	01	7·505120	62881	12·494880	49
12	542906	57936	999997	01	542909	57933	457091	48
13	577668	53641	999997	01	577672	53642	422328	47
14	609853	49938	999996	01	609857	49939	390143	46
15	639816	46714	999996	01	639820	46715	360180	45
16	667845	43881	999995	01	667849	43882	332151	44
17	694173	41372	999995	01	694179	41373	305821	43
18	718997	39135	999994	01	719003	39136	280997	42
19	742477	37127	999993	01	742484	37128	257516	41
20	764754	35315	999993	01	764761	35136	235239	40
21	7·785943	33672	9·999992	01	7·785951	33673	12·214049	39
22	806146	32175	999991	01	806155	32176	193845	38
23	825451	30805	999990	01	825460	30806	174540	37
24	843934	29547	999989	02	843944	29549	156056	36
25	861662	28388	999988	02	861674	28390	138326	35
26	878695	27317	999988	02	878708	27318	121292	34
27	895085	26323	999987	02	895099	26325	104901	33
28	910879	25399	999986	02	910894	25401	089106	32
29	926119	24538	999985	02	926134	24540	073866	31
30	940842	23733	999983	02	940858	23735	059142	30
31	7·955082	22980	9·999982	02	7·955100	22981	12·044900	29
32	968870	22273	999981	02	968889	22275	031111	28
33	982233	21608	999980	02	982253	21610	017747	27
34	995198	20981	999979	02	995219	20983	004781	26
35	8·007787	20390	999977	02	8·007809	20392	11·992191	25
36	020021	19831	999976	02	020045	19833	979955	24
37	031919	19302	999975	02	031945	19205	968055	23
38	043501	18801	999973	02	043527	18803	956473	22
39	054781	18325	999972	02	054809	18327	945191	21
40	065776	17872	999971	02	065806	17874	934194	20
41	8·076500	17441	9·999969	02	8·076531	17444	11·923469	19
42	086965	17031	999968	02	086997	17034	913003	18
43	097183	16639	999966	02	097217	16642	902783	17
44	107167	16265	999964	03	107202	16268	892797	16
45	116926	15908	999963	03	116963	15910	883037	15
46	126471	15566	999961	03	126510	15568	873490	14
47	135810	15238	999959	03	135851	15241	864149	13
48	144953	14924	999958	03	144996	14927	855004	12
49	153907	14622	999956	03	153952	14927	846048	11
50	162681	14333	999954	03	162727	14236	837273	10
51	8·171280	14054	9·999952	03	8·171328	14057	11·828672	9
52	179713	13786	999950	03	179763	13790	820247	8
53	187985	13529	999948	03	188036	13532	811964	7
54	196102	13280	999946	03	196156	13284	803844	6
55	204070	13041	999944	03	204126	13044	795874	5
56	211895	12810	999942	04	211953	12814	788047	4
57	219581	12587	999940	04	219641	12590	780359	3
58	227134	12372	999938	04	227195	12376	772805	2
59	234557	12164	999936	04	234621	12168	765379	1
60	241855	11963	999934	04	241921	11967	758079	0
	Cosine		Sine		Cotang.		Tang.	

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·241855	11963	9·999934	04	8·241921	11967	11·758079	60
1	249633	11768	999932	04	249102	11772	750898	59
2	256694	11580	999929	04	256765	11584	743835	58
3	263042	11398	999927	04	263115	11402	736885	57
4	269681	11221	999925	04	269956	11225	730044	56
5	276614	11050	999922	04	276691	11054	723309	55
6	283243	10883	999920	04	283323	10887	716677	54
7	289773	10721	999918	04	289856	10726	710144	53
8	296207	10565	999915	04	296292	10570	703708	52
9	302546	10413	999913	04	302634	10418	697366	51
10	308794	10266	999910	04	308884	10270	691116	50
11	8·314954	10122	9·999907	04	8·315046	10126	11·684954	49
12	321027	9982	999905	04	321122	9987	678878	48
13	327016	9847	999902	04	327114	9851	672886	47
14	332924	9714	999899	05	333025	9719	666975	46
15	338753	9586	999897	05	338856	9590	661144	45
16	344504	9460	999894	05	344610	9465	655390	44
17	350181	9338	999891	05	350289.	9343	649711	43
18	355783	9219	999888	05	355895	9224	644105	42
19	361315	9103	999885	05	361430	9108	638570	41
20	366777	8990	999882	05	366895	8995	633105	40
21	8·372171	8880	9·999879	05	8·372292	8885	11·627708	39
22	377499	8772	999876	05	377622	8777	622378	38
23	382762	8667	999873	05	382889	8672	617111	37
24	387962	8564	999870	05	388092	8570	611908	36
25	393101	8464	999867	05	393234	8470	606766	35
26	398179	8366	999864	05	398315	8371	601685	34
27	403199	8271	999861	05	403338	8276	596662	33
28	408161	8177	999858	05	408304	8182	591696	32
29	413068	8086	999854	05	413213	8091	586787	31
30	417919	7996	999851	06	418068	8002	581932	30
31	8·422717	7909	9·999848	06	8·422869	7914	11·577131	29
32	427462	7823	999844	06	427618	7830	572382	28
33	432156	7740	999841	06	432315	7745	567685	27
34	436800	7657	999838	06	436962	7663	563038	26
35	441394	7577	999834	06	441560	7583	558440	25
36	445941	7499	999831	06	446110	7505	553890	24
37	450440	7422	999827	06	450613	7428	549387	23
38	454893	7346	999823	06	455070	7352	544930	22
39	459301	7273	999820	06	459481	7279	540519	21
40	463665	7200	999816	06	463849	7206	536151	20
41	8·467985	7129	9·999812	06	8·468172	7135	11·531828	19
42	472263	7060	999809	06	472454	7066	527546	18
43	476498	6991	999805	06	476693	6998	523307	17
44	480693	6924	999801	06	480892	6931	519108	16
45	484848	6859	999797	07	485050	6865	514950	15
46	488963	6794	999793	07	489170	6801	510830	14
47	493040	6731	999790	07	493250	6738	506750	13
48	497078	6669	999786	07	497293	6676	502707	12
49	501080	6608	999782	07	501298	6615	498702	11
50	505045	6548	999778	07	505267	6555	494733	10
51	8·508974	6489	9·999774	07	8·509200	6496	11·490800	9
52	512867	6431	999769	07	513098	6439	486902	8
53	516726	6375	999765	07	516961	6382	483039	7
54	520551	6319	999761	07	520790	6326	479210	6
55	524343	6264	999757	07	524586	6272	475414	5
56	528102	6211	989753	07	528349	6218	471651	4
57	531828	6158	999748	07	532080	6165	467920	3
58	535523	6106	999744	07	535779	6113	464221	2
59	539186	6055	999740	07	539447	6062	460553	1
60	542819	6004	999735	07	543084	6012	456916	0
	Cosine		Sine		Cotang.		Tang.	M.

Distance	¼ Deg.		½ Deg.		¾ Deg.		Distance
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·00	1·00	0·01	1·00	0·01	1
2	2·00	0·01	2·00	0·02	2·00	0·03	2
3	3·00	0·01	3·00	0·03	3·00	0·04	3
4	4·00	0·02	4·00	0·03	4·00	0·05	4
5	5·00	0·02	5·00	0·04	5·00	0·07	5
6	6·00	0·03	6·00	0·05	6·00	0·08	6
7	7·00	0·03	7·00	0·06	7·00	0·09	7
8	8·00	0·03	8·00	0·07	8·00	0·10	8
9	9·00	0·04	9·00	0·08	9·00	0·12	9
10	10·00	0·04	10·00	0·09	10·00	0.13	10
11	11·00	0·05	11·00	0·10	11·00	0·14	11
12	12·00	0·05	12·00	0·10	12·00	0·16	12
13	13·00	0·05	13·00	0.11	13·00	0·17	13
14	14·00	0·06	14·00	0·12	14·00	0.18	14
15	15·00	0·07	15·00	0·13	15·00	0·20	15
16	16·00	0·07	16·00	0·14	16.00	0·21	16
17	17·00	0·07	17·00	0·15	17·00	0·22	17
18	18·00	0·08	18·00	0·16	18·00	0·24	18
19	19·00	0·08	19·00	0·17	19·00	0·25	19
20	20·00	0·09	20·00	0·17	20·00	0·26	20
21	21·00	0·09	21·00	0·18	21·00	0·27	21
22	22·00	0·10	22·00	0·19	22·00	0·29	22
23	23·00	0·10	23·00	0·20	23·00	0·30	23
24	24·00	0·10	24·00	0·21	24·00	0·31	24
25	25·00	0·11	25·00	0·22	25·00	0·33	25
26	26·00	0·11	26·00	0·23	26.00	0·34	26
27	27·00	0·12	27·00	0·24	27·00	0·35	27
28	28·00	0·12	28·00	0·24	28·00	0·37	28
29	29·00	0.13	29·00	0·25	29·00	0·38	29
30	30·00	0·13	30·00	0·26	30·00	0·39	30
31	31·00	0·14	31·00	0.27	31·00	0·41	31
32	32·00	0·14	32·00	0·28	32·00	0·42	32
33	33·00	0·14	33·00	0·29	33·00	0·43	33
34	34·00	0·15	34·00	0·30	34·00	0·45	34
35	35·00	0·15	35·00	0·31	35·00	0·46	35
36	36·00	0·16	36·00	0·31	36·00	0·47	36
37	37·00	0·16	37·00	0·32	37·00	0·48	37
38	38·00	0·17	38·00	0·33	38·00	0·50	38
39	39·00	0·17	39·00	0·34	39·00	0·51	39
40	40·00	0·17	40·00	0·35	40·00	0·52	40
41	41·00	0·18	41·00	0.36	41·00	0·54	41
42	42·00	0·18	42·00	0·37	42·00	0·55	42
43	43·00	0·19	43·00	0·38	43·00	0·56	43
44	44·00	0·19	44·00	0.38	44·00	0·58	44
45	45·00	0·20	45·00	0·39	45·00	0·59	45
46	46·00	0·20	46·00	0·40	46·00	0·60	46
47	47·00	0·21	47·00	0·41	47·00	0·62	47
48	48·00	0·21	48·00	0·42	48·00	0·63	48
49	49·00	0·21	49·00	0·43	49·00	0·64	49
50	50·00	0·22	50·00	0·44	50·00	0·65	50
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	89¾ Deg.		89½ Deg.		89¼ Deg.		

Distance.	1 Deg.		1¼ Deg.		1½ Deg.		1¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·02	1·00	0·02	1·00	0·03	1 00	0·03	1
2	2 00	0·03	2·00	0 04	2·00	0·05	2 00	0·06	2
3	3 00	0·05	3·00	0·07	3·00	0·08	3·00	0·09	3
4	4·00	0·07	4·00	0·09	4·00	0·10	4·00	0·12	4
5	5·00	0·09	5·00	0.11	5·00	0·13	5·00	0·15	5
6	6·00	0·10	6·00	0·13	6·00	0·16	6·00	0·18	6
7	7·00	0·12	7·00	0·15	7·00	0·18	7·00	0·21	7
8	8·00	0·14	8·00	0 17	8·00	0·21	8·00	0·25	8
9	9·00	0·16	9·00	0·20	9·00	0·24	9·00	0·28	9
10	10·00	0·17	10·00	0·22	10·00	0·26	10 00	0·31	10
11	11·00	0·19	11·00	0·24	11·00	0·28	10·99	0·34	11
12	12 00	0·21	12·00	0·26	12·00	0·31	11·99	0·37	12
13	13·00	0·23	13·00	0·28	13·00	0·34	12·99	0·40	13
14	14·00	0·24	14·00	0·31	14·00	0·37	13·99	0·43	14
15	15·00	0·26	15·00	0·33	14·99	0·39	14·99	0·46	15
16	16·00	0·28	16·00	0·35	15·99	0·42	15·99	0·49	16
17	17·00	0·30	17·00	0·37	16·99	0·45	16·99	0·52	17
18	18·00	0·31	18·00	0·39	17·99	0·47	17·99	0·55	18
19	19·00	0 33	19·00	0·41	18·99	0·50	18·99	0·58	19
20	20·00	0·35	20·00	0·44	19·99	0·52	19·99	0·61	20
21	21·00	0·37	21·00	0·46	20·99	0·55	20·99	0·64	21
22	22 00	0·38	21 99	0·48	21·99	0·58	21·99	0·67	22
23	23·00	0·40	22·99	0·50	22·99	0·60	22 99	0·70	23
24	24·00	0·42	23·99	0·52	23·99	0·63	23·99	0·73	24
25	25·00	0·44	24·99	0·55	24·99	0·65	24·99	0·76	25
26	26·00	0·45	25·99	0·57	25·99	0·68	25·99	0·79	26
27	27·00	0·47	26·99	0 59	26·99	0·71	26·99	0 83	27
28	28·00	0·49	27·99	0·61	27·99	0·73	27·99	0·86	28
29	29·00	0·51	28·99	0·63	28·99	0·76	28·99	0·89	29
30	30·00	0·52	29·99	0·65	29·99	0·79	29.99	0·92	30
31	31·00	0·54	30·99	0·68	30·99	0·81	30.99	0·95	31
32	32·00	0·56	31·99	0·70	31·99	0·84	31·99	0·98	32
33	32·99	0·58	32·99	0·72	32·99	0·86	32·98	1·01	33
34	33·99	0·59	33·99	0·74	33·99	0·89	33·98	1 04	34
35	34·99	0·61	34·99	0·76	34·99	0·92	34·98	1·07	35
36	35·99	0·63	35·99	0·79	35·99	0·94	35·98	1·10	36
37	36·99	0·65	36·99	0·81	36·99	0·97	36·98	1·13	37
38	37·99	0·66	37·99	0·83	37·99	0·99	37·98	1·16	38
39	38·99	0·68	38·99	0·85	38·99	1·02	38·98	1·19	39
40	39·99	0·70	39·99	0·87	39·99	1·05	39·98	1·22	40
41	40.99	0·72	40·99	0.89	40·99	1·07	40·98	1·25	41
42	41·99	0·73	41·99	0·92	41·99	1·10	41·98	1·28	42
43	42·99	0·75	42·99	0·94	42·99	1·13	42·98	1·31	43
44	43·99	0·77	43·99	0·96	43·99	1·15	43·98	1 34	44
45	44·99	0·79	44·99	0·98	44·99	1·18	44·98	1·37	45
46	45·99	0·80	45·99	1·00	45·99	1·20	45·98	1·40	46
47	46·99	0·82	46·99	1·03	46·99	1·23	46·98	1·44	47
48	47·99	0·84	47·99	1·05	47·99	1·26	47·98	1·47	48
49	48·99	0·86	48·99	1·07	48·99	1·28	48·98	1·50	49
50	49·99	0·87	49·99	1·09	49·99	1·31	49·98	1·53	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89 Deg.		88¾ Deg.		88½ Deg.		88¼ Deg.		

′	0°	1°	2°	3°	4°	5°	6°	7°	′
0	·000 0000	·017 4551	·034 9208	·052 4078	·069 9268	·087 4887	·105 1042	·122 7846	60
1	2909	7460	035 2120	6995	070 2191	7818	3983	123 0798	59
2	5818	·018 0370	5033	9912	5115	·088 0749	6925	3752	58
3	8727	3280	7945	·053 2829	8038	3681	9866	6705	57
4	·001 1636	6190	·036 0858	5746	·071 0961	6612	·106 2808	9658	56
5	4544	9100	3771	8663	3887	9544	5750	·124 2612	55
6	7453	·019 2010	6683	·054 1581	6899	·089 2476	8692	5566	54
7	·002 0362	4920	9596	4498	9733	5408	·107 1634	8520	53
8	3271	7830	·037 2509	7416	·072 2657	8341	4576	125 1474	52
9	6180	·020 0740	5422	·055 0333	5581	·090 1273	7519	4429	51
10	9089	3650	8335	3251	8505	4200	·108 0462	7384	50
11	·003 1998	6560	·038 1248	6169	·073 1430	7138	3405	·126 0339	49
12	4907	9470	4161	9087	4354	·091 0071	6348	3294	48
13	7816	·021 2380	7074	·056 2005	7279	3004	9291	6249	47
14	·004 0725	5291	9988	4923	·074 0203	5938	·109 2234	9205	46
15	3634	8201	·039 2901	7841	3128	8871	5178	·127 2161	45
16	6542	·022 1111	5814	·057 0759	6053	·092 1804	8122	5117	44
17	9451	4021	8728	3678	8979	4738	·110 1060	8075	43
18	·005 2360	6932	·040 1641	6596	·075 1904	7672	4010	·128 1030	42
19	5269	9842	4555	9515	4829	·093 0606	6955	3986	41
20	8178	023. 2753	7469	·058 2434	7755	3540	9899	6943	40
21	·006 1087	5663	·041 0383	5352	·076 0680	6474	·111 2844	9900	39
22	3996	8574	3296	8271	3606	9409	5789	·129 2858	38
23	6905	·024 1484	6210	·059 1190	6532	·094 2344	8734	5815	37
24	9814	4395	9124	4109	9458	5278	·112 1680	8773	36
25	·007 2723	7305	·042 2038	7029	·077 2384	8213	4625	·130 1731	35
26	5632	·025 0216	4952	9948	5311	·095 1148	7571	4690	34
27	8541	3127	7866	·060 2867	8237	4084	·113 0517	7648	33
28	·008 1450	6038	·043 0781	5787	·078 1164	7019	3463	·131 0607	32
29	4360	8948	3695	8706	4090	9955	6410	3566	31
30	7269	·026 1859	6609	·061 1626	7017	·096 2890	9356	6525	30
31	·009 0178	4770	9524	4546	9944	5826	·114 2303	9484	29
32	3087	7681	·044 2438	7466	·079 2871	8763	5250	·132 2444	28
33	5996	·027 0592	5353	·062 0386	5798	·097 1699	8197	5404	27
34	8905	3503	8268	3306	8726	4635	·115 1144	8364	26
35	·010 1814	6414	·045 1183	6226	·080 1653	7572	4092	·133 1324	25
36	4724	9325	4097	9147	4581	·098 0509	7039	4285	24
37	7633	·028 2236	7012	·063 2067	7509	3446	9987	7246	23
38	·011 0542	5148	9927	4988	·081 0437	6383	·116 2936	·134 0207	22
39	3451	8059	·046 2842	7908	3365	9320	5884	3168	21
40	6361	·029 0970	5757	·064 0829	6293	·099 2257	8832	6129	20
41	9270	3882	8673	3750	9221	5194	·117 1781	9091	19
42	·012 2179	6793	·047 1588	6671	·082 2150	8133	4730	·135 2053	18
43	5088	9705	4503	9592	5078	·100 1071	7679	5015	17
44	7998	·030 2616	7419	·065 2513	8007	4009	·118 0628	7978	16
45	·013 0907	5528	·048 0334	5435	·083 0936	6947	3578	·136 0940	15
46	3817	8439	3250	8356	3865	9886	6528	3903	14
47	6726	·031 1351	6166	·066 1278	6794	·101 2824	9478	6866	13
48	9635	4263	9082	4199	9723	5763	·119 2428	9830	12
49	·014 2545	7174	·049 1997	7121	·084 2653	8702	5378	·137 2793	11
50	5454	·032 0086	4913	·067 0043	5583	·102 1641	8329	5757	10
51	8364	2998	7829	2965	8512	4580	·120 1279	8721	9
52	·015 1273	5910	·050 0746	5887	·085 1442	7520	4230	·138 1685	8
53	4182	8822	3662	8809	4372	·103 0460	7182	4650	7
54	7093	·033 1734	6578	·068 1732	7302	3399	·121 0133	7615	6
55	·016 0002	4646	9495	4654	·086 0233	6340	3085	·139 0580	5
56	2912	7558	·051 2411	7577	3163	9280	6036	3545	4
57	5821	·034 0471	5328	·069 0499	6094	·104 2220	8988	6510	3
58	8731	3383	8244	3422	9025	5161	·122 1941	9476	2
59	·017 1641	6295	·052 1161	6345	·087 1956	8101	4893	·140 2442	1
60	4551	9208	4078	9268	4887	·105 1042	7846	5408	0
′	89°	88°	87°	86°	85°	84°	83°	82°	′

′	83°	84°	85°	86°	87°	88°	89°	′
0	8·1 443464	9·5 143645	11·430052	14·300666	19·081137	28·636253	57·289962	60
1	636786	410613	468474	306096	187930	877650	58·234174	59
2	830041	679068	507154	421230	295922	29·122066	59·265872	58
3	8·2 025239	949022	546093	482273	404133	371706	60·307820	57
4	234484	9·6 220486	585294	543483	515584	624409	61·382905	56
5	434685	493475	624761	605516	627206	882249	62·490154	55
6	635547	768000	664495	668529	740203	30·144019	63·630741	54
7	837579	9·7 044075	704500	731679	854591	411580	64·855008	53
8	8·3 040586	321713	744779	795372	970219	682307	66·165773	52
9	244577	600927	785333	859016	20·087109	959928	67·401854	51
10	448558	881732	826167	924417	205553	31·241577	68·750687	50
11	653536	9·8 164140	867282	989784	325308	528292	70·163346	49
12	862519	448166	908682	15·055723	446486	820516	71·615070	48
13	8·4 070515	733823	950370	122242	569115	32·118699	73·138991	47
14	279531	9·9 021125	992349	189349	693220	421265	74·720165	46
15	489573	310088	12·034622	257052	818828	730205	76·380069	45
16	700651	600724	077192	325358	945966	33·045173	78·126342	44
17	912772	893050	120062	394276	21·074661	368194	79·948230	43
18	8·5 125943	10·018708	163236	463814	204940	694566	81·847041	42
19	340172	048283	206716	533081	336851	34·027306	83·843507	41
20	555468	078031	250505	604784	470101	367771	85·939791	40
21	771838	107954	294609	676233	605620	716115	88·142672	39
22	989290	138054	339028	748357	742509	35·065546	90·463936	38
23	8·6 207833	168332	383768	821105	881251	421282	92·908457	37
24	427475	198789	428831	894545	22·021710	780455	95·489477	36
25	648223	229428	474221	968687	163286	36·177705	98·217042	35
26	870088	260249	519942	16·043482	308097	576153	101·10690	34
27	8·7 093077	291255	565997	118998	454096	976905	104·17004	33
28	317198	322447	612390	195225	602015	37·377842	107·42048	32
29	542461	353827	659125	272174	751892	778813	110·89205	31
30	768874	385397	706205	349855	903756	38·188459	114·59005	30
31	996440	417158	753634	428279	23·057677	617728	118·51018	29
32	8·8 225186	449112	801417	507456	213666	39·050771	122·77936	28
33	455109	481261	849557	587396	371777	505895	127·02184	27
34	686206	513607	898058	668112	532052	965460	132·21851	26
35	918565	546151	946924	749614	694567	40·435837	137·50745	25
36	8·9 152009	578895	996160	831915	859277	917412	142·93712	24
37	386720	611841	13·045769	915025	24·026320	41·410588	149·46502	23
38	622668	644992	095757	998957	195714	915790	156·25908	22
39	859843	678348	146127	17·083724	367509	42·433464	163·70019	21
40	9·0 098261	711913	196883	169337	541758	964077	171·88540	20
41	337033	745687	248031	255809	718512	43·508122	180·89220	19
42	578107	779673	299574	343155	897826	44·066113	190·98419	18
43	821074	813872	351518	431295	25·079757	635596	202·21875	17
44	9·1 064564	848288	403867	520516	264361	45·220141	214·85762	16
45	309348	882921	456625	610559	451700	829351	229·18106	15
46	555436	917775	509799	701529	641832	46·448862	245·55198	14
47	802828	952850	563391	793442	834823	47·085343	264·44080	13
48	9·2 051564	988150	617409	886310	26·030796	739501	286·47773	12
49	301627	11·023676	671856	980150	229038	48·412084	312·52137	11
50	553035	059431	726738	18·074977	431600	49·103881	343·77371	10
51	805862	095416	782060	170807	636090	815726	381·97099	9
52	9·3 059036	131635	837827	267654	844984	50·548506	429·71757	8
53	315459	168089	894045	365537	27·056057	51·303157	491·10000	7
54	572355	204780	950719	464471	271486	52·080073	572·95721	6
55	830663	241712	14·007856	564473	489853	882109	687·54887	5
56	9·4 090384	278885	065459	665562	711740	53·708587	859·43630	4
57	351531	316304	123536	767754	937233	54·561300	1145·9153	3
58	614116	353970	182092	871068	28·166422	55·441517	1718·8732	2
59	878149	391885	241134	975523	399297	56·350590	3437·7467	1
60	9.5 143645	430052	300666	19·081137	636253	57·289962	Infinite.	0
′	6°	5°	4°	3°	2°	1°	0°	′

PRICE-LIST OF INSTRUMENTS.

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